The Role of *Garsa* (*Dobera glabra)* for Household Food Security at Times of Food Shortage in Aba`ala Wereda, North Afar: Ecological Adaptation and Socio-economic Value

A Study from Ethiopia

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D. glabra wild fruit

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Drylands Coordination Group
TØRRLANDS-KOORDINERINGSGRUPPEN
GROUPE DE COORDINATION DES ZONES ARIDES

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The founding DCG members consist of ADRA Norway, CARE Norway, Norwegian Church Aid, Norwegian People's Aid, The Strømme Foundation and The Development Fund. The Secretariat of DCG is located at the Environmental House (Miljøhuset G9) in Oslo and acts as a facilitating and implementing body for the DCG. DCG's activities are funded by NORAD (the Norwegian Agency for Development Cooperation).

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ABSTRACT

Based on the overall rationale of the research project assessing the role of *Dobera glabra* for household food security, many studies and tests have been made. A semi-structured interview has been administered to selected respondents and groups to reveal information on the socio-economic and cultural aspects of this plant. The socio-economic surveys revealed that *D. glabra* is a highly valued plant species with diverse importance such as drought food and feed source, a tool for forecasting the coming of drought and thus an early warning tree. The germination requirement of *D. glabra* has been tested by undertaking germination trials for different treatments and different seed forms at Aba'ala demonstration site. The germination trials included the following three types of experiments:

1. Germinability of seed forms (Gid`a, Garsa and Gallolo) as treatments and replicating them three times with a time interval of one month each (storage time).
2. The two seed forms (Gid`a and Garsa), treated in boiled water, soaked in cold water for 24hrs, pierced and a control (untreated).
3. Garsa seed forms of *D. glabra* were subjected to three watering frequencies applied daily, every other day and weekly[1].

The percentage data from the germination experiments were analyzed using JMP 5 statistical software and the Tukey-kramer HSD test was run to compare differences in treatment means within experiments. The germination trial result revealed that no germination viability variation was observed as a result of storage (3 months). However, treating *D. glabra* seeds has brought a positive effect in shortening the germination time. Germination results of the different watering frequencies showed a significant difference (P<5%) in germination percentage when seeds were watered every other day. Different water types from three different localities were tested to see if the long cooking time was caused by the local type of water. The cooking trial showed no significant difference in the length of cooking time although rainwater and the highland Kwhia water brought some relative improvement by reducing the cooking time. Vegetative propagation from stem cuttings was also tested. Two types of stem cutting lengths (sizes) were used of 15cm and 20cm. Experimental results of stem cuttings show that *D. glabra* cannot perpetuate through the stem cutting method of propagation.

No empirical data was available on the nutritive value and chemical composition of *D. glabra* except that it is believed to be an important browse for domestic animals particularly camels. Thus, this study was conducted to analyze and document the chemical composition and nutritive value of edible parts of this plant and also to measure its distribution in the Kala rangeland of Aba`ala. To address these objectives transect sampling was done to collect plant and soil samples. Laboratory analysis was done for CP, Ca, P, K, Mg and Na of edible forage and different fruit parts. Soil chemical analysis was also done for CaCO3, OM, OC, EC and PH. The result revealed that *D. glabra* is one of the most important species in the rangeland and the edible fruit and folliage have good nitrogen content except that the Ca/P ratio is much greater. The general total ash content is high, 21% for the leaves and 8% for the fruit on average. The result implies that *D. glabra* is high in mineral content as believed by the pastoralists. The CP content is also high to support animals' requirements if browsed well. Laboratory analysis on the nutritive value of the edible fruit part of *D. glabra* also revealed that this plant has nutritive value nearly comparable to most common wild food fruits.

Based on the findings of this study, there is a need to give more attention to this endangered plant through appropriate propagation and protection measures. Results from all germination trials also

[1] Only Gersa seed types were used because these are the ones that showed a higher level of germination in the last experiments.

indicate that the best way to propagate the plant is by using seed, as in almost all the germination trials about 80% of all the seeds germinated. It can also be concluded that the findings of this study can serve as baseline information to encourage the local people to propagate this endangered plant and suggest further investigation related to pest problems and animal browsing influences. Based on the findings of the study, more in-depth scientific studies are required on the effect of browsing and habitat factors on natural recruitment, effect of storage period on seed viability, and survival of transplanted and naturally established seedlings.

Key words: *D. glabra*, drought, germination, seed forms, watering frequency, stem cuttings, and propagation.

ACRONYMS

ANOVA	Analysis of Variance
CRD	Completely Randomized Design
DBH	Diameter at Breast Height
DM	Dry Matter
DSH	Diameter at Stump Height
EC	Electrical Conductivity
GE	Gross Energy
GIS	Geographic Information System
GPS	Global Positioning System
HCl	Hydrochloric acid
OC	Organic Carbon
OM	Organic Matter
Ns	Not significant
RCBD	Randomized Complete Block Design
UN-EUE	United Nation Emergency Unit for Ethiopia
UNDP-EUE	United Nations Development Program Emergency Unit for Ethiopia
UTM	Latitude and Longitude coordinate point in meters

1. INTRODUCTION

1.1 BACKGROUND INFORMATION

The use of wild plants as sources of food for humans seems more common and widespread in food insecure areas. Local people, from their own experience, know about the importance and contribution of these plants to their daily diet, as well as being aware of possible health and environmental hazards.

Among the wild food plants found in the Afar Region is *Dobera glabra*, locally known as *'Garsa'*. The plant grows in dry areas, on saline, heavy, or calcareous loam soils and on rocky hillsides (UN-EU, 2001). It grows abundantly in dry and moist lowland areas (400 - 1,300 m above sea level). In Afar region, the *D. glabra* tree is abundantly found in three administrative zones (Zone 2, Zone 4 and Zone 5) and can easily be recognized at times of drought because of its deep green color. The settlements found along the Mile-Bati road in Zones 5 and 4 are called 'Garsa Gita', which means 'the place where *D. glabra* trees are found'. Afar pastoralists have a proverb saying: 'the one who finds *D. glabra* is lucky and will not suffer'. Finding a *D. glabra* tree at times of drought is a good sign for somebody suffering from hunger, because he knows that he will survive. At several occasions, when interviewing Afar people during dry spell periods near water points and questioning them about wild food consumption, *D. glabra* is the first they usually mention. They also present samples of cooked or fresh fruits, which indicate that people are consuming the seed (UN-EU, 2001).

D. glabra produces edible fruits and the seed is considered a typical 'famine-food'. The Afar pastoralists appreciate its drought indicator qualities. They indicate that new shoots always grow during the dry season. If rains are delayed or fail, the tree typically shows an enhanced production of new shoots, fruits and seeds. In normal times, when rains are on time or abundant, *D. glabra* does not produce much fruit and seed. When the tree blooms and produces fruits abundantly, people think that a drought may very well be under way and hence fear that food may become scarce.

Afar people in Aba'ala wereda also explain that 'Garsa' is an important tree for camels. They say that the plant is a good browse and is known as a mineral supplement plant to camels.

Although the importance of *D. glabra* is highly appreciated by the local people in terms of food source and livestock feed and its adaptability to the area, there are some critical problems regarding this valuable plant as mentioned by the pastoralists. Among many other problems the main one as stated by the local people is that they do not see new generations (young seedlings) of *D. glabra* this time. Only old trees are available. This is an indication that the plant is highly endangered and that extinction of the plant in the near future is inevitable if nothing is done.

It is in light of the above related problems that this research was initiated.

1.2 PURPOSE AND OBJECTIVES

The broad objective of the study was to assess the role of the wild fruit (*D. glabra*) in alleviating food shortages during drought periods and its importance as drought indicator and other local uses (ecological adaptations and socio-economic values). The specific objectives of the study are: Specific objectives of the study were:

- To assess the role of the wild fruit (*D. glabra*) for the local people during drought periods;
- To identify problems associated with the failure of natural regeneration (germination) and evaluate germination at Nursery;

- To identify problems related to long periods of cooking;
- To retrieve information from the local people regarding ecological, cultural, and social peculiarities of the plant;
- To assess the spatial distribution and structural composition of the species
- To determine the best watering frequency for optimum germination;
- To examine if the presence or removal of fruit structure and seed coat have an effect on seed germination;
- To select the best seed pre-treatment method;
- To select the best stem cutting length that give better performance;
- To determine the nutritive value of the edible part of the seed;
- To examine, evaluate and understand the requirements of successful propagation of *D. glabra* from seeds and stem cuttings;
- To determine the chemical composition and nutritive value of *D. glabra* seed and edible foliage;
- To evaluate the nutritional quality of the seed and browse parts of the plant (*D. glabra*);
- To identify the relationship between the soil and plant chemical composition.

2. DESCRIPTION OF THE STUDY AREA

2.1 LOCATION

This study was conducted in Aba'ala Wereda located in Zone 2 of the northern part of Afar Regional State, northeastern Ethiopia. This area is also located at about 55Km southeast of Mekelle town. The elevation of Aba'ala ranges from1000-1500m above sea level. The study locality where *D. glabra* is available is Kala plain located 30 Km South East of Aba'ala town. The site covers a total area of 60 km^2 that represents the largest part of Kala plain (Figure 1). The administrative and geographical location of the study area is summarized below:

Administrative location

Administrative region:	Afar
Zone:	Two
Wereda (District):	Aba'ala
Locality:	Kala plain

Geographic location (UTM)

- Latitude: 13011' to 13017' N
- Longitude: 39048' to 39054' E

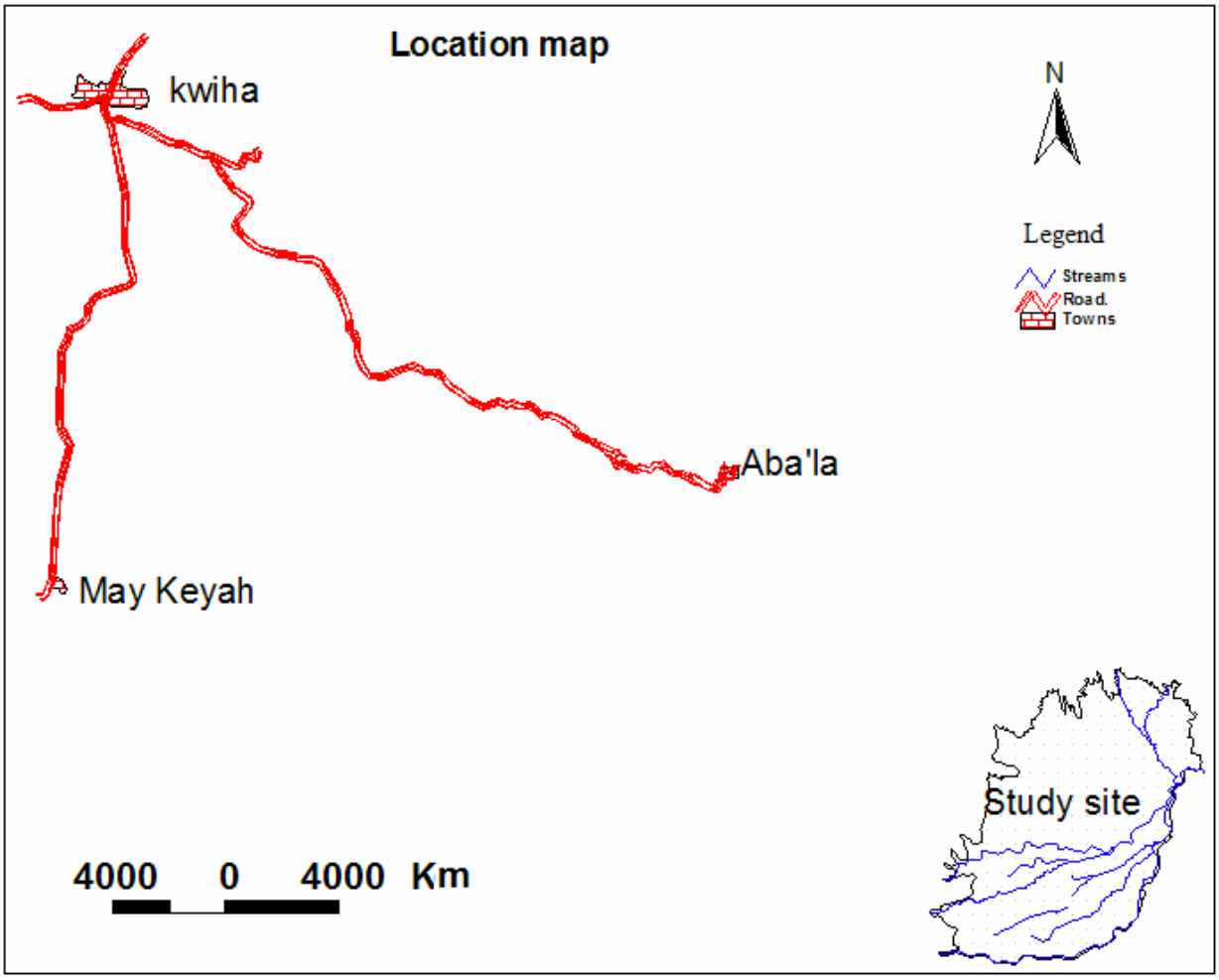

Figure 1: Location map

2.2 CLIMATE

A semi-arid type of climate receiving a bimodal rainfall characterizes this area. The short rain occurs in Sugum (March and April). The main rain comes in Karma occurring between June and September (UN-EUE, 2000). The rainfall is generally characterized by its erratic and scattered nature with an annual average value of 422 mm for the period of 1972-1979 (Ethiopian Metrological Agency, Shiket station record). Figure 2 also shows the distribution of rainfall in Aba`ala Wereda for the recent years (2001-2004).

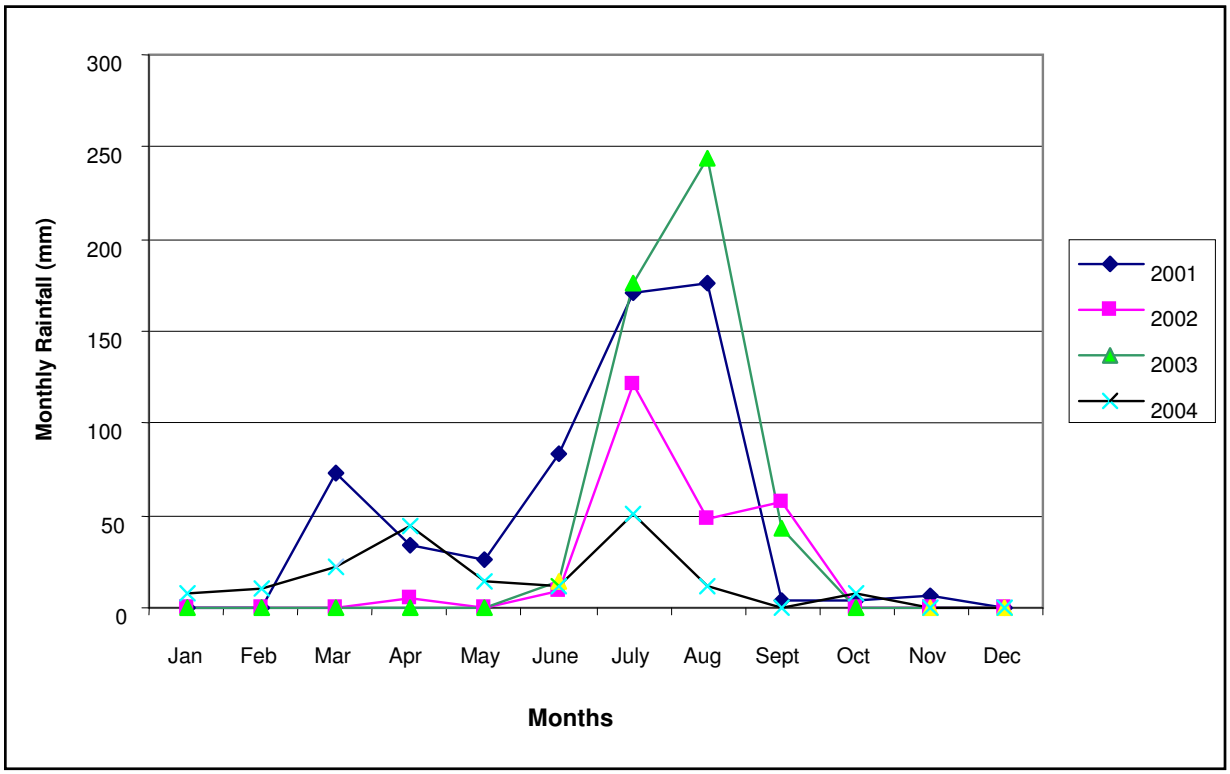

Figure 2: Monthly rainfall distribution of Aba'ala for the years 2001-2004.

2.3 PHYSIOGRAPHY AND SOILS

The study area consists of flat plains occasionally interrupted by undulating hills and series of elongated ridges, surrounded by high broken hills with few outlets joined to other valleys. The topography is a mix of flood plains, mountainous areas with moderate relief intensity, and rugged areas with steep slopes and high relief intensities. There are few perennial rivers in the study area, which flow eastwards but sink into the sand within very few kilometers from their sources (Diress, 1999). The dominant soil textures identified in the study area include clay loam, loam, clay and silt clay. Clay textured soil is mainly found in the upper part of the watershed where arable land use is the major land use type. Clay loam is the most dominant one and is found almost through out the watershed area. The upper part of the watershed, near the foot of the hills, is dominantly covered by alluvial deposits with poor pedogenic profile formation.

2.4 LIVESTOCK

In the study area goats, sheep, cattle, camel and donkey are the major livestock classes kept by the mixed Tigrinya agro-pastoralists and the native Afar pastoralists. The average number of livestock per household and the total numbers in the Wereda are indicated in Table 1.

Table 1: Livestock population of Aba'ala Wereda

Livestock Class	Total Population	Average livestock no./household
Goat	67,352	12
Sheep	33,306	6
Cattle	29,605	5
Camel	21,834	4
Donkey	4,441	1

Source: Aba'ala veterinary section annual report (1996).

2.5 VEGETATION OF THE STUDY AREA AND DESCRIPTION OF *D. GLABRA*

Vegetation of the study area consists of bush land dominated by *Acacia etbaica* with many associated trees and shrubs (Diress *et al*. 1999). Poor herbaceous cover mainly annuals and few perennial grasses are the key features of the rangeland in the study area (Diress *et al*. 1999, Diress *et al*. 2003). In Kala plain *D. glabra* is usually found as straightly standing tree with round crown and sometimes as a fallen tree with spreading branches (Figure 3). Such diverse structure of the species makes it accessible for browsing both by large and small animals like camel and goats.

Figure 3: Fallen trees (left) and standing trees (right)

Dobera glabra belongs to the family S*alvadoracea. Dobera* is a genus of two species both occurring in the tropical Africa and one extending to India. The two are closely related but are certainly distinct. These two species are *Dobera loranthifolia* and *Dobera glabra.* The former occurs in Kenya and Somalia and may possibly be found in Ethiopia. The later is surely found in many lowlands of Ethiopia (Azene, 1993).

Following its distribution *D. glabra* has many local (vernacular) names in the different areas of Ethiopia as karsata (konsogna), Garsa (Afarigna), domaye (Gamogna), garas, haras (Somaligna) and geresa (Tigrigna). It is in general a slow growing but hard plant once established and is sensitive to water logging (Azene, 1993).

2.5.1 Ecology

According to Azene (1993), *D. glabra* is a shrub that grows on rocky hillsides in dry areas and on saline, heavy or calcareous loam soils. This plant thrives well in dry and moist kola agro climatic zones, 400-1300m a.s.l. It is also observed in Hirum rangeland (in Aba'ala wereda), which is situated at an elevation of 1158m a.s.l (personal observation).

2.5.2 Morphological features

Azene (1993) described *D. glabra* as a branched ever green shrub or a tree that grows up to a height of 8m. The barks are green to dark grey and patchy. Leaves are opposite, yellow to green-grey, thick smooth; veins- hardy green, up to 7cm long; tip- usually notched; flowers-white in branched heads. The fruit is ovoid about 2cm long, with 1-2 flat seeds in a soft edible pulp. It was

also identified that the fruit has three parts locally called Gallallo, Gid'a and Garsa (Diress et al, 2004; unpublished 1st year technical report). The types of the fruit (Figure 4) include:

Gallolo: is the whole matured fruit of the plant consisting of the kernel, red edible pulp and the inner most green cotyledons.

Gid'a: the seed part beneath the red covered with white, thin membrane like a coat. This is the part of the seed left over after humans, monkeys, baboons and birds have eaten the fruit. The people (pastoralists) mostly collect the Gid'a to store for a drought period reserve.

Garsa: it is the inner most green cotyledon part next to Gid`a after the white coat has been removed. It is this part of *D. glabra* that can be cooked for human consumption. The red flesh part sandwiched between the outer peeled cover (kernel), and the white inner coat of the seed is what can be eaten by humans, birds and other wild animals like monkeys and baboons during harvesting. This part has a sweet sugary substance with its own characteristic smell.
These include:

Figure 4: The four forms of fruit of *D. glabra*

2.5.3 Method of propagation

Even though seeds of *D. glabra* should be sown directly into pots, do not need treatment necessarily and do not store well, *D. glabra* has a means of perpetuating its kind. The principal method of reproduction is direct sowing and wildling (Azene, 1993).

3. MATERIALS AND METHODS

3.1 MATERIALS

The following materials were used during the study

- Topographic maps
- GPS
- GIS software (ILWIS 3.2)
- Clinometer
- Calliper
- Hypsometer
- Measuring tape
- Farm tools
- Laboratory and computer facilities
- Chemicals:
  - H_2SO_4
  - HCl
  - Distilled water
  - Selenium
  - Powdered NaOH
  - H_2O_2
  - Salicylic acid
  - Boric acid
  - Potassium molybidat
  - Ascorbic acid

3.2 METHODS

3.2.1 Distribution and structural composition of *D. glabra*

To understand the distribution of *D. glabra* along river/stream, part of the drainage line, called Kulahitu, was selected and every tree was marked with GPS and the tree variables were measured.

To know the distribution of the species in a large part of the open plain, 54 systematic square plots were laid in the field with 0.25 ha area. The plot centres were identified from the topographic map and laid in the field using GPS.

For every tree/shrub identified in the plots and along part of the kulahitu river line, the following variables were measured:

Diameter: Diameter at Breast Height (DBH) at 1.3m above the ground for trees and Diameter at Stump Height (DSH) at 0.3m above the ground for shrubs and bushes was measured using calliper.

Crown diameter: two perpendicular measurements were made using a measuring tape and the average is taken as the diameter of the crown. Then, percent crown cover was calculated by dividing the crown areas of tree by plot area.

Height: Total and bole heights: were measured using a clinometer and sometimes directly by climbing.

Number of stems per ha: is estimated taking the number of trees identified in the plots and dividing it by the area in hectare (Philip, 1994).

Spatial distribution pattern: Point data interpolation techniques called moving average and trend analyses were generated using GIS. To make the moving average map readable, it was stretched using histogram equalization. Moving surface point data interpolation was used to get the spatial distribution in the study area. In moving surface interpolation, surface is calculated by a moving least squares fit; for each output pixel, the surface will approach the weighted point values of the points which fall within the specified limiting distance. The output map (figure 9), is a raster map with assigned values of calculated surface values for every pixel (ITC, 2001).

Maps and area: were generated using GIS
The general work approach is summarised in Figure 5.

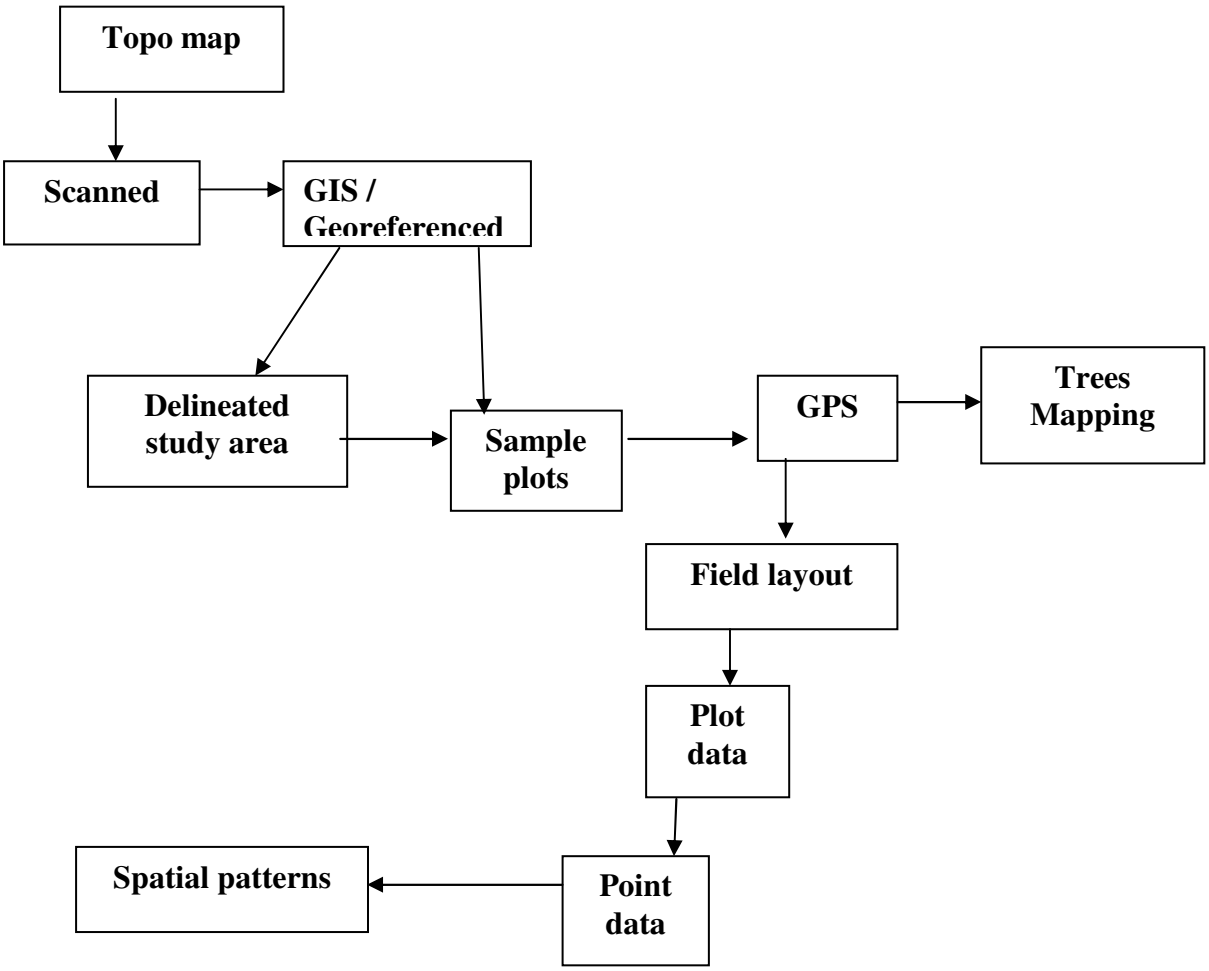

Figure 5: Method framework

3.2.2 Determination of physico-chemical characteristics of soils in relation to *D. glabra* distribution

Based on the distribution of *D. glabra* and other vegetation cover, three transects were set up using GPS across the gradient of woody vegetation cover. On each transect, quadrats of 20mx20m were established at the interval of 200m to collect soil samples. Soil samples were taken from each quadrat at 10cm, 20cm and 30cm depth of the upper layer. Soil samples were also collected from a distant area with no *D. glabra* distribution at all.

The chemical composition (Na, K, Mg, Ca, Chlorides and Sulfates) of the soil from Kala rangeland and other areas where *D. glabra* is not abundantly found was determined. Na and K were analyzed using the Flem method procedure whereas Ca and Mg were determined using the Ammonium Acetate method. The other parameters like PH and EC were however estimated after water suspension (Okalebo, Gathua and Woomer, 2002).

3.2.3 Socio-economic survey

Information regarding the ecological, cultural and social peculiarities of *D. glabra* was collected by interviewing the Afar herders in the study area. About 30 pastoralists were interviewed from Kala-Haridan area, Adiharemelle, Dinemelle, Eka, Bahrine villages. The respondents were intentionally selected based on their knowledge about the use of the plant. Emphasis was given to the ecological diversity, problems of natural regeneration, and importance of the plant during drought and major cooking problems.

3.2.4 Germination experiments

Germination trial I: effect of storage time after harvesting

The germination trial was done using polythene tubes. Twenty seeds from each type of seed (Gallolo, Gid'a and Garsa) were planted in three replications. The replication was based on the age of the seeds after harvesting. The first trial was on July 15, the 2nd on August 15, and the 3rd on September 12, 2004. This was done to evaluate the germination ability of the seeds after a certain period of storage. Data on the number of seeds germinated each day were collected from the trial at Aba'ala nursery site. No watering limitation is considered in this experiment. It was watered twice a day (in the morning and afternoon).

Germination trial II: Effect of pre-sowing seed treatments for the two seed forms (Garsa & Gid'a) in year 1 (2004)

For this trial the two seed forms (Garsa & Gid'a) were used and they were treated with different mechanisms. Overall there were four treatments used with three replications to test germination capacity of the two seed forms using pots. The treatments include:

- Soaking in boiled water for five minutes;
- Soaking in cold water for 24 hrs;
- Piercing of both Gid'a and Garsa seeds with a pin; and
- Control.

During the experiment water was not considered to be the limitation but to minimize the logging effect the pots were watered only once a day as the bottom of the pots may accumulate water. A record of the number of seeds germinated was taken every day to select the best treatment that gives a good germination rate.

Figure 6: Left: Germination trial for different seed forms, Middle: germination trial for different pre-sowing treatments, Right: Germination trial visit by DCG coordinator.

Germination trial III: Effect of pre-sowing seed treatments for the three seed forms (Gallolo, Gid'a and Garsa) in year 2 (2005)

For this experiment, a randomized complete block design (RCBD) looked into two variables. The variables were the structurally different seed forms or types of *D. glabra* and the different pre sowing treatments (soaking in cold water for 24 hours, soaking in boiled water for 5 minutes, piercing (pinning), and with no pre-sowing treatments (as control). Each pre-sowing treatment was applied to all the different seed forms (Garsa, Gid'a and Gallalo) of *D. glabra*. Each treatment contained 16 seed forms from each of the mentioned seed types in a pot. And data on germination count, after germination start up, was taken daily for 36 days. Watering, from sowing to last day of data recording, was done once a day, early in the morning.

Germination trial IV: Effect of different watering frequencies

Aiming to select the best watering frequency for an optimum germinability of the Garsa seed types, the trial was done on a polythene tube at Aba'ala demonstration site (nursery). To facilitate germination, the Garsa seed types were soaked for 24 hours before sowing (a seed type – pre sowing treatment combination that showed the best results in the last experiments). The trial had three post sowing treatments of watering frequencies, namely each day (F_1) as a control, one day and every other day (F_2), and once every week (F_3). The post sowing treatments were replicated three times and for a single treatment in a replication the number of Garsa seeds used was 110, one seed per every polythene tube.

As water was the limiting factor for this trial, two things were done. First, to avoid high surface evaporation, the seeds were watered early in the morning and late in the afternoon. Second, to avoid the effect of rainwater, a plastic cover (shade) was used. Fortunately, there was only one light rain during the whole course of the experiment. In addition, data on the number of germinated seeds (germination count), and thus of the germination energy were recorded on a daily basis.

3.2.5 Propagation trials from stem cutting

To run this trial, a one-factor design i.e. complete randomized design (CRD) was used. And the design looked into stem cutting lengths of 15cm (T_1) and 20cm (T_2), as a treatment. The treatments were replicated four times. Nine stem cuttings were used for each replication.

3.2.6 Determination of chemical composition and nutritive value of *D. glabra* edible foliage

Leaves and twigs collected from the plant were oven dried, grounded and sieved (at 1mm sieve) and used for the determination of DM, Gross energy (GE), Soluble carbohydrate, total nitrogen, and some major plant mineral Cations (P, K, Ca, Mg and Na) contents.

Proximate analysis of Kjeldah block digester method was selected for the determination of crude protein. Similarly, the samples were digested in block digester and all the analysis of soluble carbohydrate and mineral cations was done using the procedures presented by Okalebo, Gathua and Woomer (2002).

3.2.7 Nutrient analysis of the edible part of the fruit

Kjeldahl Markham's method (1942) was used to determine the nutritive values of the edible parts of *D. glabra* seed. The nutritive values are then put as a percentage gram of dry matter.

3.2.8 Cooking trial

Guided by the indigenous knowledge of the people in the area, the Garsa seed was cooked with four water types (rain water, Kwiha tap water, Aba'ala river water and Aba'ala underground tap water). Cooking was done after the white cover of Gid`a was removed and the cotyledons were separated by the experienced Afar ladies (Figure 7). The whole process was, in fact, carried out through the involvement of the Afar women.

Then, data on the time taken to completely cook the seed for human consumption was collected and analyzed.

Figure 7: Cooking trial by Afar women

4. RESULTS AND DISCUSSION

4.1 DISTRIBUTION AND STRUCTURAL COMPOSITION OF *D. GLABRA*

During the field visit, it was observed that the distribution of *D. glabra* along streams is higher than the open field. Thus, to get more information, data was collected along the Kuhulaito stream (top part) by locating every single tree with GPS and tree variables such as height (total bole), diameter (stem, crown) and regeneration conditions were recorded. The distribution of trees on the top part of the stream is indicated in Figure 8.

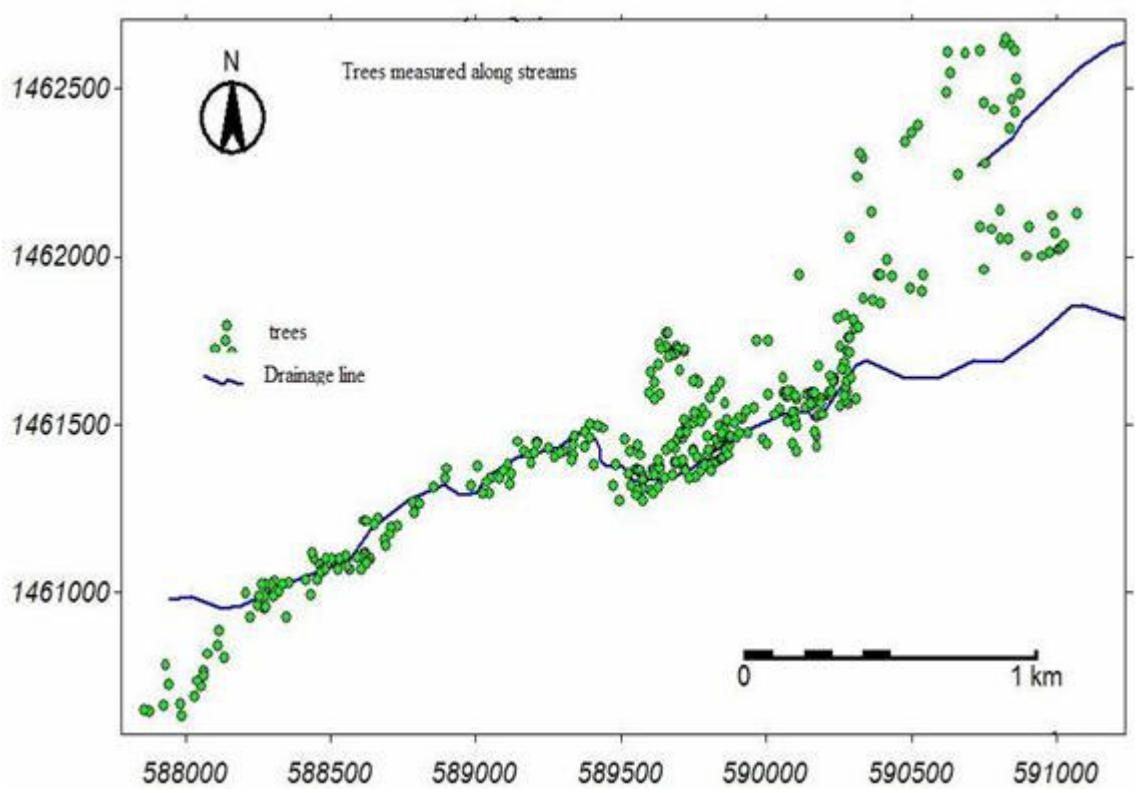

Figure 8: Trees along the Kulahitu drainage line

Similar data on height (total bole), diameter (stem, crown) and regeneration conditions were also studied from 54 plots in the plain area far from the riverine areas.

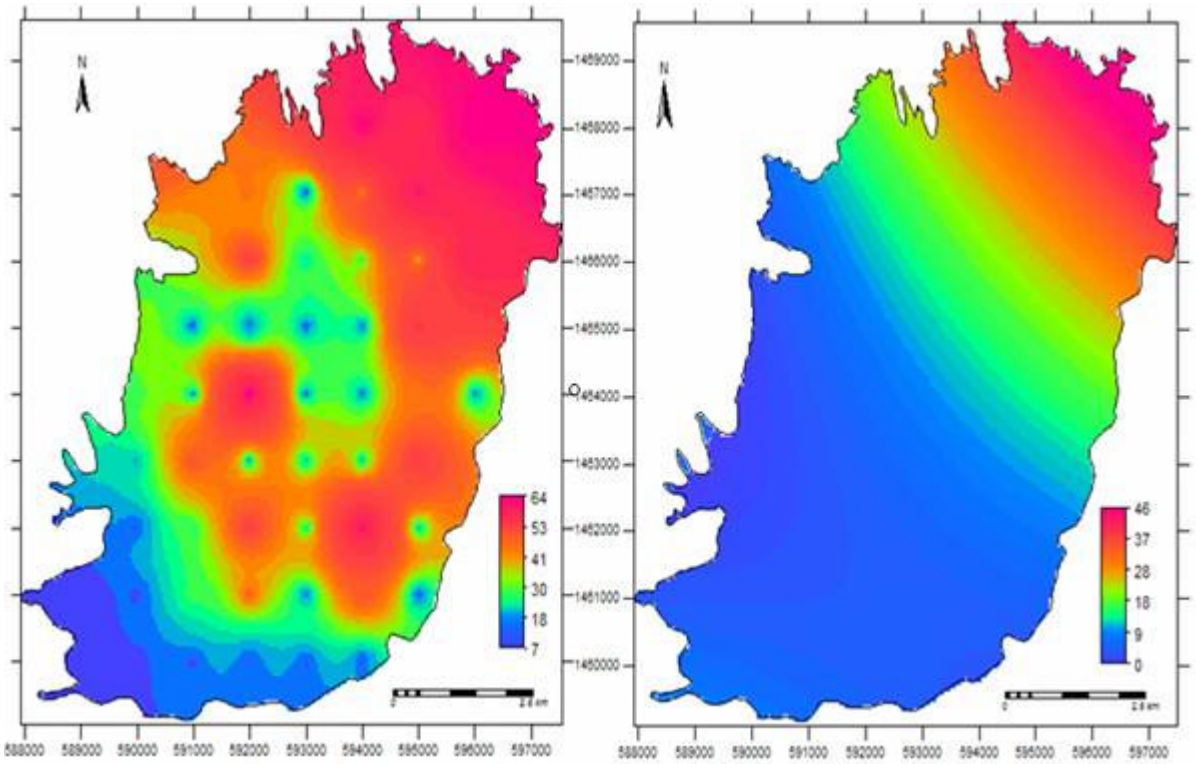

Figure 9: Spatial distribution of *Dobera glabra* in kalah plain

4.1.1 Attributes related to *D. glabra* distribution

Spacing: The average spacing between trees along the streams is about 7m while only 41 trees were estimated to exist in one hectare paths of open field (plain area) from the plot sampling. The result confirmed that the distribution of *D. glabra* is denser along river lines which makes it one of the major riverine vegetation species in the Kala plain.

This investigation clearly supports previous results as reviewed by Bekele (1993), *D. glabra* is becoming a reverine vegetation of southern Konso areas as a result of human impact of deforestation even if it is also among the most abundant woody vegetation components in Kala plain (Mohammed, 2004).

Crown diameter: The average crown diameter of *D. glabra* trees for both riverine and plain areas was found to be 4m and the distribution of the different crown diameter classes is indicated in Figure 10.

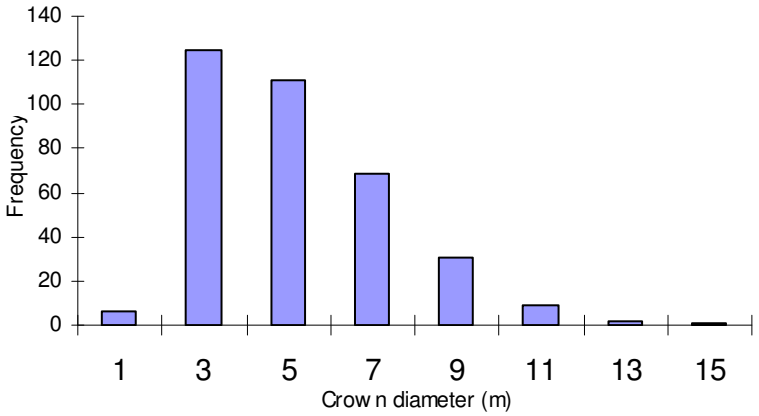

Figure 10: Crown diameter distribution of D. glabra trees along rivers

The crown cover of the study area by *D. glabra* is about 2%. Crown cover indicates the proportion of the land being covered by the vertical projection of crown perimeter of the tree and is commonly expressed as a percent of total ground area. The DBH and DSH distribution is indicated in Figure 11.

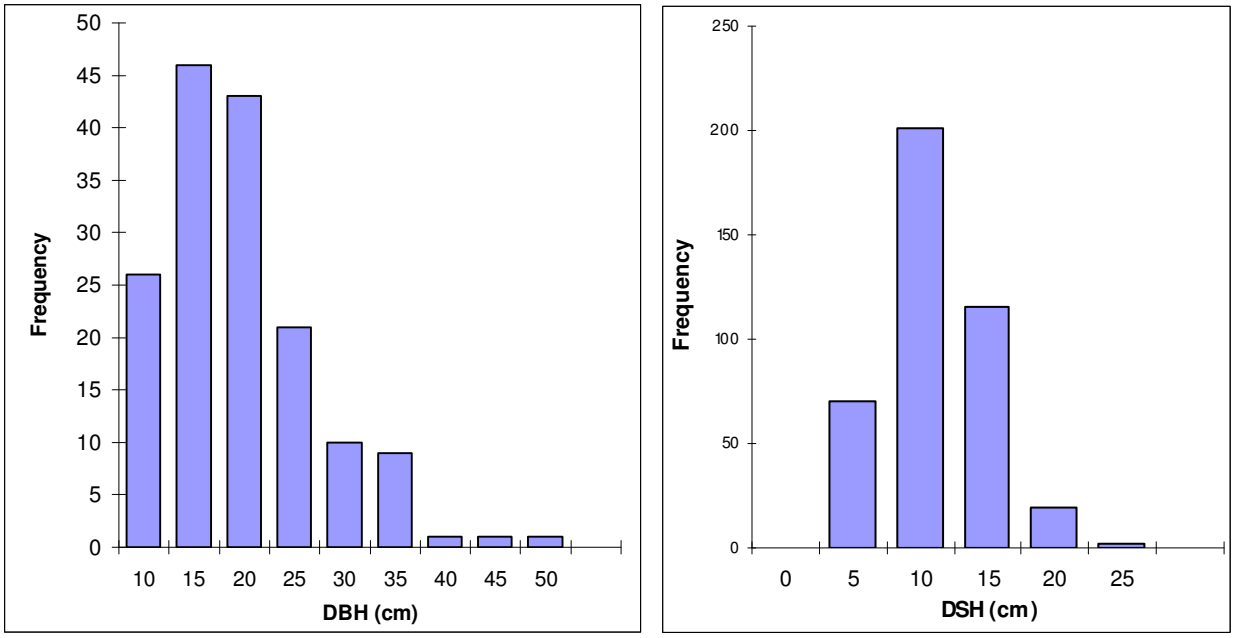

Figure 11: Diameter at Breast Height (DBH), left & Diameter at Stump Height (DSH), right

Height: The average height of *D. glabra* is 3m and 2.6m along the riverine and plain areas, respectively (Figure 12).

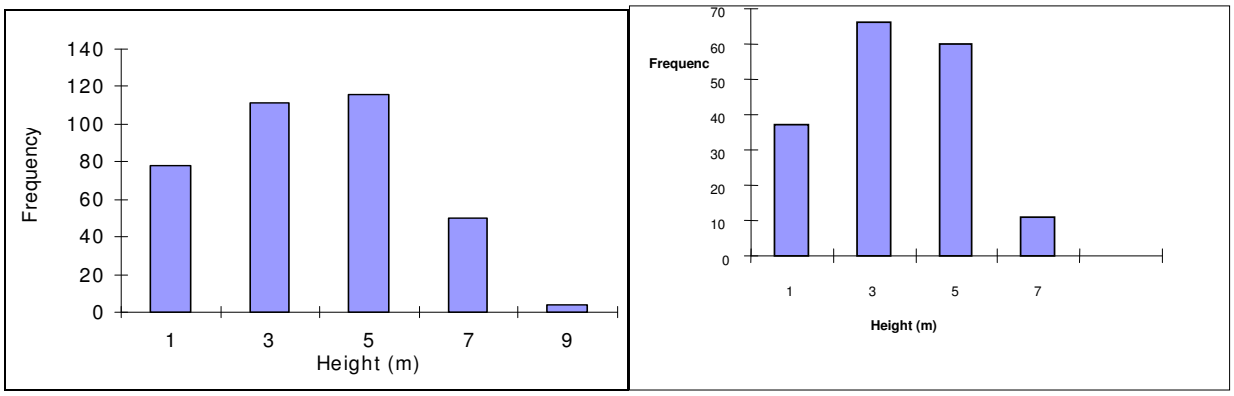

Figure 12: Height distribution of trees in the riverine (left) and open Kala plain (right)

Number of trees per hectare: Taking the data from the 54 plots, each with 0.25ha, the average trees per plot and hectare are 10 and 41 respectively. As a result the total number of trees found in the plain (6000ha) is estimated to be 248,000. The range of trees in the different plots varies from 66 to none which indicates the non uniformity of *D. glabra* distribution in the plain.

Since the range or trees per hectare for every plot is very wide, it is difficult to read the legend. Thus, the number of trees per plot presented in fig. 9 indicates the spatial distribution of *D. glabra* in the study area.

From field observation, most *D. glabra* trees were found lying on the ground. In figure 12 (height frequency distribution in the open field), it is also clearly indicated that there are numerous trees at

one and three meters height. In this respect, height has important connotations as only trees and shrubs below a certain height can be browsed by livestock.

It is in general easy for management as a browse for domestic animals. On the other hand, t*he D. glabra* trees might have been shaped to remain short by browsers due to repeated browsing effects. Under a normal situation the tree might reach 7-10 meters in height. However, it should be noted that most *D. glabra* tree height measurements do not clearly indicate age as those trees lying on the ground are not measured for their total length, but for their effective ground height. This phenomenon is also an indication of high browsing impact by large animals like camels.

Despite its hydrological implications, crown cover is also important in estimating the effect of grazing (Kindeya, 2003) and burning (Herlocker, 1999). Even though a detailed research comparison of grazing and browsing impact is required to come up with a tangible and reliable conclusion, it has been observed in the field that most *D. glabra* trees at the reach of animals are severely browsed. The average crown diameter is about 4 meters which implies that the majority of trees encountered are big trees rather than small seedlings/ saplings. This clearly shows that *D. glabra* has lost its regeneration or recruitment ability and is under threat in the study site.

The general distribution of *D. glabra* in Kala plain, as indicated from the raster map of the study area, is very poor at the south western borders, along the edge of Dergha River (e.g. Boliso). In this area many plots are found to be empty for *D. glabra* count. From plain observation, the soil at Boliso site is mainly dominated by clay loam with many alluvial materials. Nevertheless, *D. glabra* was relatively denser at the northern and eastern parts of the plain (Kuhulaito and Hirum). The western parts of the plain have a unique land surface feature with many rock outcrops, an eroded surface and coarse sandy loam nature of the soil. This agrees with Azene *et al*.'s (1993) ecological description of the plant where it is said that it prefers rock outcrop sites. Especially at the upper streamline of Kuhulaito River, relatively many young *Dobera glabra* trees are observed. In addition, around the Northern end of the plain (Hirum) a dense and big tree count is recorded. It is clearly a tree line and hot spot of the plain. The soil is rich in litter materials and fine clay alluvial deposits. It is situated at the dispersion point of a river line. However, no new seedlings/saplings were recorded in this site. The failure of recruitment, thus, needs further investigation.

4.1.2 Physico-chemical characteristics of soils

Availability of plant nutrient is highly influenced by pH of the soil. Most of the essential elements for plant growth are largely available between 6.5 to 7-pH values. The soil reaction value (pH) of the soil samples range from high to very high (7.13-8.56); thus, they are moderately alkaline to strongly alkaline. This pH range has the following effects; in the presence of Ca, phosphate tends to be converted to calcium phosphate, and the availability of P for plants can be reduced. At this pH range boron toxicity may also occur, bacterial activity and hence nitrification of organic matter is decreased and availability of micronutrients is reduced except for molybdenum. The pH range tells us the soil is not in the optimum range for agriculture that is normally considered as between 6.5-7. In addition such pH range also favors certain soil born diseases (Table 2).

Table 2: Rating pH, EC, OC, OM and CaCo3 to different categories

Parameter	Rating	% of Soil Samples
pH	Very high (>8.5)	1.85
	High (7-8.5)	91.15
EC (ds/m)	High (>0.02)	0
	Medium (0.01-0.02)	0
	Low (<0.01)	100
O.C (%)	Low (<4)	100
O.M%	Low (< 2)	59.1
$CaCO_3$ (%)	Calcic (>15)	98.15
	Medium (<15)	1.85

The calcium carbonate values ranges from medium to high (17-26%). This may be due to the fact that the soils are derived from carbonate rich rocks. The values indicate that exchangeable Ca, which implies favorable soil physical conditions, dominates the clay complex. Excess Ca, however, can lead to deficiency of minor elements and it can have antagonizing action over other cations.

The O.C. content values of the soil samples lie between (0.7and1.4%) and are rated as low. However, determination of O.C is very sensitive and it is often made as a measure of the quantity of O.M in a soil. The low values of O.C affect the physical property of the soil e.g. water holding property of the soils to be lowered. OM is taken as a crude measure of fertility status where a general recommendation can be made using the values obtained. The organic matter in the soil samples acts as one of the major reservoirs of soil nutrient and it also makes several nutrients more available for plants. Thus, the lower values of O.M % indicate that the soil's productivity is low. This could be due to high turnover of organic residues as a result of the hot temperature and less litter supply that prevails in the area.

Overall, the soil of the study area is characterized by alkaline having low EC, OC and OM content (Fig 13).

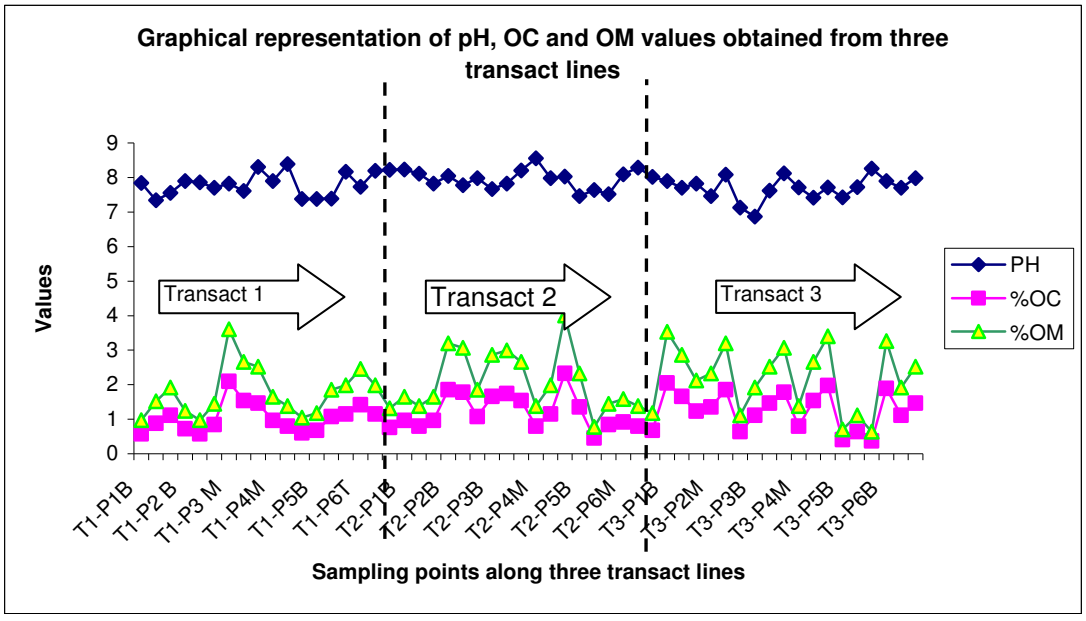

Figure 13: Graphical representation of pH, %OC and %OM values obtained from three transects

Statistical analysis of the physico-chemical data shows that there is high variance on measurement of EC data while there is more standard deviation on measurement of organic matter (Table 3). This could be related to the variation in position of the site from which the samples were collected. It indicates the presence of spatial variability in terms of these soil properties.

Table 3: Result of basic statistical analysis of chemical soil properties

Statistical parameters	**Soil –data**				
	pH	**EC**	**$CaCo_3$**	**%OC**	**%OM**
Max	8.56	1935.80	25.573	2.32	4.003
Min	6.87	2.321	17.370	0.37	0.639
Mean	7.82	339.36	24.88	1.173	2.020
SD	0.335	396.57	1.554	0.490	0.846
Var	0.11	157268.93	2.416	0.241	0.716

In order to see the relationship between the variables, correlation and covariance analysis was made. The result shows that the relationship among the variables is generally positive but low except for the covariance value between EC * $CaCo_3$ and EC * OC (Table 4).

Table 4: Correlation and covariance relationship of two dependent soil characteristics

Functions	**Related Variables**	**Value**
Correlation	pH * OM	0.07
Covariance	pH *OM	0.02
Correlation	EC * $CaCo_3$	0.099
Covariance	EC * $CaCo_3$	60.49
Correlation	EC * OC	0.237
Covariance	EC * OC	45.347

Spatial variability of soils is the function of soil forming factors. As a result of variation in these soil forming factors, soil varies from place to place. In essence, soil could vary over short distances if the responsible factors vary substantially. A measure of relationship (correlation) was applied between distances (0, 400m, 800m, 1200m, 1600m and 2000m) and soil chemical data obtained from samples of the same transect line. This was compared again with the result of the other transect lines. No defined relationship was obtained within and among the transect line (s); and this shows that the area is largely consisting of the same materials irrespective of its location (Table 5)

Table 5: Spatial variability of soil chemical properties as a function of distance

Function	**Variables**	**Value**	**Remark**
Correlation	PH * Distance	0.547	Transect 1
	EC * Distance	-0.253	
	CaCo3 * Distance	0.424	
	%OM * Distance	0.174	
Correlation	PH * Distance	-0.114	Transect 2
	EC * Distance	0.120	
	CaCo3 * Distance	0.168	
	%OM * Distance	-0.392	
Correlation	PH * Distance	0.404	Transect 3
	EC * Distance	-0.178	
	CaCo3 * Distance	-0.227	
	%OM * Distance	-0.409	

By looking the values of pH and OM, the soil is generally categorized as less fertile. However, the plant (*D. glabra*) grows in dry areas, on saline, heavy, or calcareous loam soils and on rocky hillsides (UN-EU, 2001). It grows abundantly in dry and moist lowland areas (400 - 1,300m).

Little is known about the soil, climate and water requirement of *D. glabra*. On the basis of previous studies and closer observations, *D. glabra* may not require fertile soil. It can grow in areas with low fertility and low rainfall distribution. The main reason for the absence of new seedlings and the reduction of plant population in the area could be due to lesser amount of soil moisture during germination of the new seeds coming from lower organic matter content and intensive browsing of young seedlings by animals rather than the fertility of the soil. This needs further investigation.

4.2 SOCIO-ECONOMIC SURVEY

In this part of the study, socio-economic issues related to *D. glabra* were assessed. The main issues addressed include ecological status and natural regeneration problems, socio-economic importance to the pastoralists, cultural beliefs and traditional management practices.

4.2.1 The status and natural regeneration of *D. glabra*

Like other rangeland trees and shrubs, *D. glabra* has also a means to perpetuate its kind. According to the majority of the respondents, regeneration is by means of seed although it is hardly possible to observe newly germinated seedlings in Kala rangeland these days. However, some of the respondents indicated that it could also be propagated by means of layering. Some of the seeds, as suggested by these people, can also germinate into two seedlings /shoots per seed. This has also been observed in the field. The pastoralist's view regarding the population trend of this plant through time is indicated in Table 6.

Table 6: Pastoralists' observation on population trend of *D. glabra* in Kala rangeland

Population Trend	**Number of respondents**	**%**
Decreasing	20	66.7
Increasing	7	23.3
Difficult to predict	3	10
Total	30	100

The majority of the respondents in the increasing category are residents of Erebti Wereda where there are no settlement and cultivation activities. But 66% of the total respondents believed that *D. glabra* is being endangered in the Kala rangeland. These people have also tried to find reasons for this reduction in abundance, cover and density as summarized in Table 7.

Table 7: Reasons for the reduction of *D. glabra* in abundance from Kala rangeland

Reasons	**Number of respondents**	**%**
Inadequate rainfall	12	40
Tree cutting	9	30
Shift in browsing of domestic and wild animals on *D. glabra* due to overgrazing of the rangeland	9	30
Grazing land shortage due to other land use practices	8	26.6
Seedling damage by insects and worms	4	13.3
Unknown germination problem	4	13.3
Total	46*	253.2

*The total number of respondents exceeds 30 as some gave more than one possible answer.

Although inadequate rainfall is more emphasized to be the major cause of reduction in density and abundance, tree cutting, increased influences on the leaves, seeds and fruits by domestic and wild animals are also largely mentioned as causes for this phenomenon. For instance, rodents like squirrels, domestic animals mainly camels and goats are supposed to be the major causes of seed and seedling destruction beneath the tree. This situation also coincides with the status of this plant in Konso area where it remained a riverside vegetation of Segen River as a result of intensive deforestation activities (http://www.africa.upenn.edu/faminefood.htm). Although the local people did not mention it, the fruit harvest for domestic use might have also contributed to the reduction of the plant population.

The pastoralists, however, mainly emphasized that the major cause is rainfall shortage as explained by Kala, Adiharemelle and Dinemelle respondents. Their idea could be highly supported for the reason that the rainfall distribution of the study area is highly variable and this is justified by the four years rainfall distribution as shown in figure 1.

Similarly, a study by the World Bank and GTZ in Yemen indicates that in the *Dobera-Balanites* parkland of Jebel Bura, one of the remnant natural vegetation areas, *D. glabra* is failing to produce any regeneration (www.brainworker.ch/reports/yemen.htm). Only old trees of *D. glabra* are available and are being replaced by the hardier and thorny species of *Ziziphus* and *Balanities* through time. This situation should then attract the attention of more researchers in finding the root causes of the problem.

One of the peculiarities of *D. glabra* is its deep green color among other rangeland vegetations during dry season. The pastoralists understood from their many years of acquaintance with this plant that it favors dry, hot and windy whether condition to produce soft, green and highly palatable leaves and twigs. The conducive environment for *D. glabra*, as suggested by the people, is a plain area with light brown and white colored heavy saline soil. They also suggest that it needs dry windy and hot whether conditions to bloom and bear seeds and fruits. This is evidenced by the fact that the plant flowers and sets fruits during the hottest season of the year (i.e. during May and June). During the main rainy season, it looks unattractive and hard as compared to the dry season appearances.

Most of the elders interviewed in Aba'ala Wereda shared their experience by saying that *D. glabra* is our natural meteorologist. It feels the environment and forecasts the bad drought if it is likely to happen. According to these peoples' perception, a profuse flowering and tillering predicts the future drought occurrences in the locality. If they observe such situations, the herders become ready to move their animals to other areas following their 'Dagu' (information exchange in the Afar culture).

4.2.2 Socio-economic importance of *D. glabra* for the pastoralists

D. glabra, *Ziziphus spina-christi, Allyto* (local name*)* and *Grewia erythrea* are the most appreciated plants by the pastoralists in Kala in terms of their economic importance. *D. glabra* and other important wild fruit plants available in the area are also listed in Table 8. The respondents ranked the plants with respect to their contribution as human and animal food source, as well as with regard to the plant's drought resistance and its importance value in the rangeland.

Before the relief aid program was launched in almost all the Afar regions of Zone two, the pastoralists lived on milk, milk products, meat and wild fruits. Although living on wild fruits seems an old tradition of life today, its contribution should not be underestimated in saving the life of many pastoralists particularly during drought. The plant is considered a live savor during the drought period and in some localities people usually collect the seeds for household use and for market. These people are called, in Afar culture, Haramiru (fruit eaters).

Table 8: Important wild fruit plants in Kala rangeland

Local name	Scientific name
Gersa	*D. glabra*
Hedaito	*Grewia erythrea*
Adaito	*Salvadora persica*
Mederto	*Cordia gharaf*
Kusraito	*Ziziphus spina-christi*
Ditita	*Grewia ferrugniea*

For these people, *D. glabra* is one of the important wild fruit plants, which plays a great role in providing human food source both under drought and normal conditions. It produces fruit once a year in May-July. These people claimed that whatever happens in May and June the herders never face severe starvation as the *D. glabra* fruit ripens by this time. Parents have also a saying to sooth their children's cry for food during this time, "no one misses at least *D. glabra* fruit in the field".

The herders particularly children and mothers are busy during fruiting time in collecting the seeds (Gid'a) to store as a human food reserve for the drought period. During collection, the herders eat the red flesh part of the fruit after removing the outer cover (locally called Gallolo). Then, they store the seeds that are covered with a white coat for household consumption. They store it in Gereb (locally made leather sack) and some others bury the seed in the soil for years. The fruit shades within a short period of time after ripening (about a month) before the rainy season starts.

If drought happens unexpectedly, it will be these stored *D. glabra* seeds together with other wild seeds, which will be their immediate source of food if there is no relief aid and lack of other interventions. The seeds of *D. glabra* and Allayto are consumed after cooking.

The people tried to explain their feeling of satisfaction after eating this meal as, "we feel just like we eat meat; we gain enough energy to work". However, they do not feel comfortable (feel tired) after eating the cooked *D. glabra* seeds without mixing with other foodstuffs.

Commercial value
The role of *D. glabra* to the pastoral society is not only limited to the fruit and seed but the woody part has also importance in making some household furniture and local timber. Even though the residents in Kala, Hirum and Haridan do not use this plant as a commercial source, people from Bahre in Erebti Wereda are experienced in using the wood of this plant to prepare some household utensils as korre (local container of porridge and milk), doors and also for fencing. They strongly emphasized that it has a strong and termite resistant timber.

One Korre, approximately a size of 10-15 liters capacity, is sold about 100.00 Birr. It takes about four days to prepare one Korre by an individual.

Medicinal value
The remote settlement and high mobility pattern of the Afars in the area have also made them very experienced in preparing traditional medicines from the locally available in their locality. *D. glabra* also plays a major role in the preparation of traditional medicines for both human and animal diseases. Table 9 shows the major human and animal diseases treated by traditional medicine prepared from different parts of *D. glabra*.

Besides its medicinal value some people also indicated that the newly growing shoot of *D. glabra* is used in the preparation of a bulletproof magic substance during war.

Table 9: Importance of *D. glabra* as traditional medicine for some human and animal diseases

Disease	Type of animals or humans	Parts used	Treatment Method
Swelling on legs and hands	Humans	Bark	The juice is used after being chopped and squeezed
Stomach problem	Humans	Water used for cooking the seed	Three cups of cooking water + a spoon of butter is administered per day
Camel eye disease (Abeb)	Camel	Leaves	Chopped and sprayed on the infected eye
Tumawo`a (infectious disease)	Human	Bark	Putting the chopped bark on the infected area
Bone breakage	Humans	Bark + Garsa (green part of the seed)	The bark and seeds are dried, grounded, and mixed together with butter and stored in a small container for some time. This will be sandwiched between the openings to fasten and relieve the pain.

D. glabra as a livestock feed

D. glabra is an important shade tree and dry season fodder source. All domestic animals feed on the leaves and twigs of this plant (Table 10). As shown in Table 10, wild animals also feed on the fruit and seed of *D. glabra*. It is especially highly used by camels in all seasons. The camel herders said, "our camels cannot stay without getting *D. glabra* feed at least once in a year. The animals spontaneously migrate to *D. glabra* growing areas particularly during the rainy season". They also strengthen this idea by adding, "anyone who lost his camels must directly go to Kala rangeland". The herders have also included some physiological reasoning why their camels run for it. They reasoned that the salt lick available along the Dergha river in Kala plain attracts camels. This also encourages the camels to feed on the leaves of *D. glabra.* The local people also indicated that the leaves may also have some minerals which attract camels in the rainy season. Anyone arriving in Kala rangeland can also observe a heap of camel waste and a characteristic odor of camels nearby the tree.

Table 10: Edible parts of *D. glabra* by domestic and wild animals

Animal	Parts eaten			
	Leaves	Twigs	Fruit (Gallolo)	Seed (Gid`a)
Camels	x	x	x	x
Goats	x	x	x	x
Cattle	x	x	*	*
Sheep	x	x	Less**	Less**
Donkeys	x	x	x	x
Monkeys	*	*	x	x
Warthogs (Hereya)	x	*	x	*
Ayawu			x	
Squirrels			x	x

X= feeding on the mentioned parts

* Not well known yet

**Sheep face severe bloating if they consume large amounts of the seed and fruit (esp. immature ones).

4.2.3 Socio-cultural beliefs and side effects after consumption

Most people did not volunteer to say, even a word, about *D. glabra* as it is assumed that discussing about *D. glabra* is an indicator of bad drought. It is therefore a cultural taboo in the study area in general to speak about wild-food sources.

The collection of seeds like *D. glabra* and others to preserve for the drought period has a further implication of lower strata among the population. However, particularly in very remote areas, some kebelles of Erebti Wereda, people are still collecting and consuming cooked D. glabra seeds even in normal time.

Nevertheless, any time when *D. glabra* fruit ripens, all ages of the population especially the herders and children pick and feed on the red flesh part.

Most wild fruits are consumed raw as they are picked. *D. glabra* fruit is also consumed immediately after it is picked. In fact, it can stay for a brief period of time in containers without being hazardous to the health. No detailed information was gained about serious side effects of eating the fruit on human health from the experience of the pastoralists. However, improperly cooked *D. glabra* seeds consumption causes stomachache (Halib in Afargna).

A study on wild food plants in southern Ethiopia by Guinad and Lemessa (2000) also indicated a similar situation in Konso area. Although, this similar research further indicates the bad smell of the cooking water, in this trial the smell was not much exaggerated during cooking. On the other hand, the local people mentioned that there is a bad smell that is felt after cooking. This may be attributed to the type of water and storage period.

The local people also identify some disorders on domestic animals. For instance, immature fruit and excess seed consumption by sheep and goats can cause severe bloating, which may even lead to death if not treated rapidly. A slight diarrhea is also common for camels for a few days when first arriving on *D. glabra* growing fields for browsing (Table 12).

Table 11: Common disorders caused by feeding on *D. glabra*

Types of Livestock and humans	**Disorders/ symptoms**	**Causes**	**Local treatment**
Camels	Diarrhea	Consumption of all parts of *D. glabra* for the first few days of arrival in the area.	No treatment
Goats and sheep	Bloating	Consumption of immature seed and fruit.	Whey + salt solution Or Salt + its own milk will be put in the sunshine and the watery part floating over the solution is administered.
Humans	Stomach ache (Halib)	Consumption of improperly boiled *D. glabra* seeds.	Ko`esina plant root + Hinyto root juice
	Diarrhea	Consumption of improperly boiled *D. glabra* seeds.	Meat stew + butter
	Vomiting	Consumption of immature fruits.	Fresh goat milk

4.2.4 Traditional management related to *D. glabra* protection in Kala rangeland

It was assumed to be a bad idea by the pastoralists to cut any parts of a live tree including *D. glabra* either for their animals or other domestic purposes (fire wood, fencing, construction, local timbering, etc.) a few years ago. For instance, the pastoralists assumed that cutting any part of *D. glabra* is suspected of bringing bad drought in the area. However, these days such management practice is being eroded and it is common to observe many branches and twigs of *D. glabra* removed from the tree in Kala rangeland. The respondents believed that this was due to overgrazing as a result of increased pressure on the rangelands. Increased expansion of settlements in the study area reduced mobility which aggravates overgrazing due to long period of grazing in few localities. Guinand and Lemessa (2000) have also supported this idea in their assessment mission of Konso areas.

4.3 GERMINATION TRIALS

4.3.1 Germination trial I: Effect of storage time after harvesting

The germination trial was conducted for about 28 days for each sowing time. The seeds were sown at a month interval between each sowing time. Figure 14 shows the number of germinated seeds for the different seed forms.

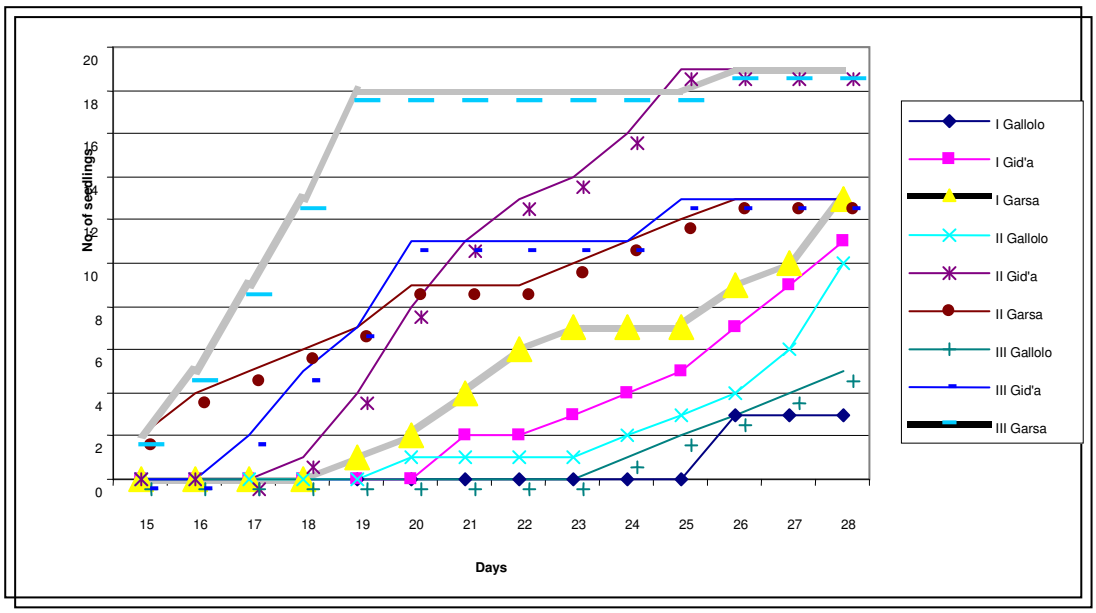

Figure 14: Trend of Germination for the different seed forms along a time interval (1-28 days)

Germination started after 15 days of sowing for all forms of seeds. All seed forms in all the sowing periods showed an increasing trend in germination rate. After germination, Gersa showed a fast germination rate in all the three replications (sowing time). However, Gallalo had a poor germination rate in all the three sowing times. ANOVA also showed a significant difference ($P<0.05$) between Garsa and Gallolo. However, Gid'a had no significant difference ($P>0.05$) with the other two seed forms. Gid'a reduced its germination time and rate during the third sowing time after it has been stored for about 3 months after harvest. The other two forms however, increased their germination ability after three months of storage. From this result it is possible to conclude that the seeds should be separated from the outer covers in order to facilitate germination of *D. glabra*.

In contrast, the time or storage influence on germination could not clearly show differences for all the seed forms. This condition implies that the seeds under normal storage (without any special care except keeping away from moisture) could not increase/ decrease the viability of the seed,

considering only three months of storage. Therefore, to come up with a general conclusion it is better to add further storage periods and observe the trend.

4.3.2 Germination trial II: Effect of pre sowing treatments in year 1 (2004)

In this experiment, four treatments (Control, Soaked, Pinned and Boiled) were compared to see the germination abilities of *D. glabra* seeds (Figure 15). The three treatments (soaking, pinning and boiling) were not applied to Gallolo. From Figure 15, it is observed that there is a significant difference ($P<0.05$) among Gersa, Gid'a and Gallolo when sown without any treatment. In general, Garsa (control, pinned and soaked) and Gid`a (soaked) showed better germination performance than Gid`a (control and pinned) and Gallolo ($p<0.05$). Gersa performed best followed by Gid'a. However, the performance of Gallolo was very poor (Figure 15).

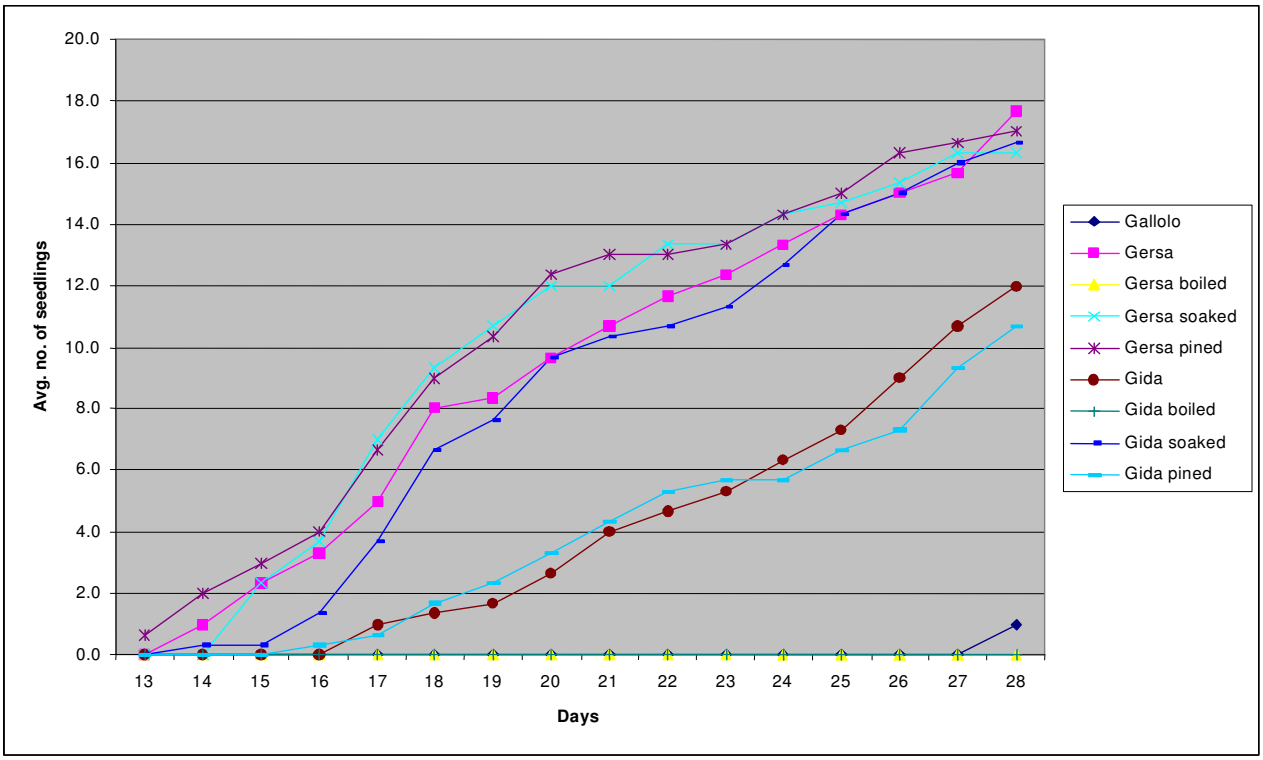

Figure 15: Germination trends of two (Garsa & Gid'a) treated seed forms

In this study, germination was observed at different dates after sowing (14, 21 and 28 days). Germination started first with the pierced seed types of Garsa at 13 days after sowing. At 14 days germination count, the treatments had no significant difference ($p>0.05$). But still the mean value of the piercing treatment is overtaking the others. However, from the target of this research, it could not be concluded that treating Garsa and Gid`a seed types has any effect in shortening the germination delay by less than 14 days (Table 12).

Table 12: Mean comparison for germinated seeds during the germination periods (Year 1)

Treatments	Mean number of seedlings at different Counting dates during the trial		
	14 days	21days	28 days
Control	0.50 [a]	5.11 [bc]	14.83 [a]
Pinned	1.00 [a]	9.50 [ab]	13.83 [a]
Soaked	0.16 [a]	12.83 [a]	16.50 [a]
Boiled	0.00 [a]	0.00 [c]	0.00 [b]

Values not connected by the same letter are significant down each column (not across the columns)

Within a week interval of germination start up, seeds soaked in cold water for 24 hours exceeded in mean value (12.83±2.47698) even though it is not significantly different from the pierced seeds ($p>0.05$) as shown in figure 15 and mean comparison Table 12. The pierced ones were not significantly different from the controls. Nevertheless, boiling has brought a negative effect on germination, all seeds failed to germinate.

The result revealed that cold water soaking brought an increase in the germination rate for both seed forms (Garsa and Gid`a). However, Garsa (without any treatment) and Garsa (pinned) showed almost a similar performance with Garsa and Gid`a soaked groups. Furthermore, the figure 15 indicates that piercing (pinning) had no effect in reducing the germination delay for Gid`a seed form. Rather it takes the longest period to attain 50 % germination. As a result, if the rainfall distribution of an area is relatively not much scattered for a month's period, keeping the other favorable environmental conditions as they are, treatment of *D. glabra* seeds has no significant effect in improving germination rate. This is perhaps an indication that the problem of adequate moisture availability contributed to the germination delay.

4.3.3 Germination trial III: Effect of pre sowing treatments (Year 2)

Three pre sowing treatments were applied to see if these treatments have an effect on the viability of the three forms of *D. glabra*. Similarly, Albrecht & Oloo (2000) categorized seeds of *D. glabra* as the ones that need specific extraction, drying, storage and pre treatment, for proper germination. The mean germination % for this trial is indicated in Table 13.

Table 13: Mean germination percentage values for the four pre-sowing treatments (year 2)

Treatments	Germination %	Std. Error
T1 (Soaking in cold water for 24 hours)	55.22^{a}	5.18
T2 (Soaking in boiled water for 5 minutes)	0^{b}	5.18
T3 (piercing or pinning)	49.50^{a}	5.18
T4 (Control)	52.21^{a}	3.54

Note: Values connected by different superscript letters are significantly different at 5% level of significance using Tukey's pair wise comparison test.

Three of the treatments (soaking in cold and boiled water and the control) did not show any difference among themselves. However, no seed germinated that was treated in boiled water. A strict follow up of the seeds for about a month indicated that no seed germinated at all. This therefore indicates that the effect of boiling is not delaying germination but it totally kills the seed. The ability of seeds to resist higher temperature, like that of seeds of *D. glabra* is not very common to most woody plants. Hartmann et al., (2004), indicated that dry seeds can withstand extreme temperature. For disease control, seeds can be placed in boiling water for a short period without killing them. In most rangelands, bush fires are often effective in overcoming dormancy without damaging seeds. Accordingly, even if more data is required to confirm this assertion, it can be said that *D. glabra* may be susceptible to extinction from bush burning.

Table 14: Mean germination percentage values for the three seed forms

Seed Forms	Germination %	Std. Error
Gid`a	51.68^{a}	4.48
Gersa	51.15^{a}	3.84
Gallolo	14.85^{b}	3.84

Note: Values connected by different superscript letters are significantly different at 5% level of significance using Tukey's pair wise comparison test.

Table 14 indicates that there is a significant difference in the germination ability of the two forms of the seed (Gid'a and Garsa) as compared to Gallolo. This is because the Gallolo form of the seed requires more moisture than the other forms because a considerable amount of moisture is devoted to moistening the karnel (the white, thick upper most cover) before the moisture reaches the internal parts of the seed which are responsible for germination. The fact that the presence of Karnel in Gallolo has significantly reduced the germination ability of the seed under well watered conditions will inevitably imply that karnel, is another reason for the failure of germination under natural conditions, especially when it is combined with a severe shortage of moisture.

Similar to the results of the other germination experiments, most seeds germinated during the 2nd week after sowing. The percentage germination (proportion of seeds that have germinated) in the third and fourth weeks are significantly different among themselves and compared to those during the 2nd week (Table 15).

Table 15: Mean germination percentage values for four weeks

Germination period (weeks)	Germination %	Std. Error
Wk1	0.05^{c}	4.79
Wk2	41.51^{b}	4.79
Wk3	54.07^{ab}	4.79
Wk4	61.29^{a}	4.79

Note: Values connected by different superscript letters are significantly different at 5% level of significance using Tukey's pair wise comparison test.

Within a week interval of germination start up, seeds soaked in cold water, for 24 hours, significantly ($p<0.05$) exceeded the other treatments in mean germination value. During the first week, the value for the seeds soaked in cold water and that of the pierced seeds, both significantly exceeded the value for the control treatment. This indicates that within a given range of moisture availability, early germination was possible with the treatment. This in turn indicates that a considerable amount of moisture is devoted in moistening the untreated seed coat as indicated by the significant delay of germination. However, the percentage germination values for the cold water soaking, piercing and the control group are not significantly different in the 3rd and 4th weeks (Table 16). This therefore, indicates that, once the seed is imbibed, it germinates at the normal rate of germination.

Table 16: Mean germination percentage for the interaction of days and treatments

Treatments	Days			
	Wk1	**Wk2**	**Wk3**	**Wk4**
T1 (soaked in cold water)	4.16^{bcd}	56.26^{ab}	75.00^{a}	85.43^{a}
T2 (soaked in boiled water)	0^{d}	0^{d}	0^{d}	0^{d}
T3 (pierced or pinned)	2.1^{cd}	54.2^{abc}	68.77^{a}	72.93^{a}
T4 (control)	0^{d}	55.56^{a}	72.52^{a}	86.81^{a}

Note: Values connected by different superscript letters are significantly different at 5% level of significance using Tukey's pair wise comparison test.

Figure 16 indicates that the germination percentage of Garsa and Gid'a was significantly higher than Gallolo.

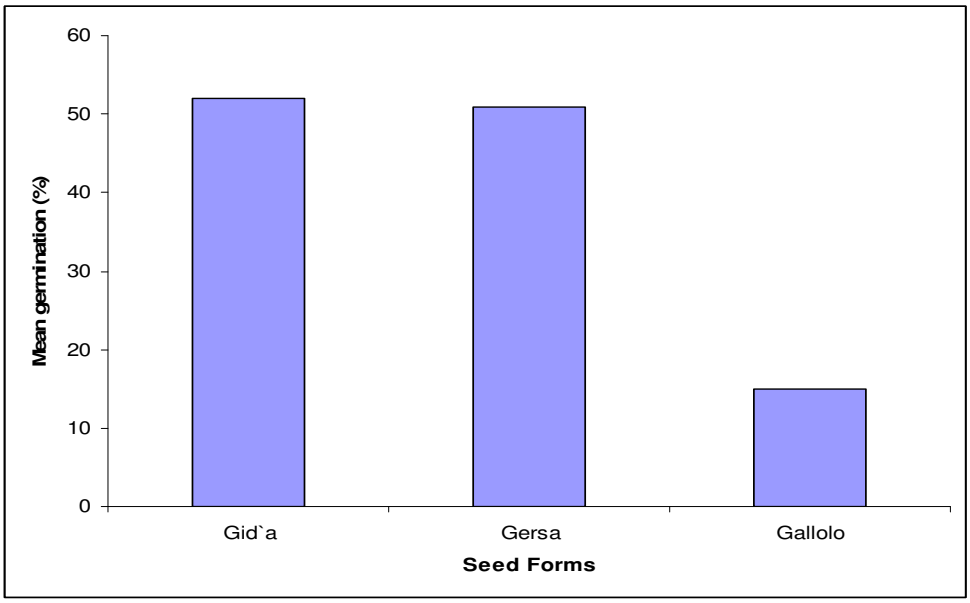

Figure 16: Mean germination (%) of interaction of treatments with seed forms

4.3.4 Germination trial IV: Effect of different watering frequencies (Year 2)

As indicated in Table 17 and Figure 17, the watering frequency that gave the higher average germination count is watering every other day. Mean germination ($P < 0.05$) significantly decreased with increased water stress (from watering every other day to watering once a week). However, an increase in the watering frequency from watering every other day to watering every day does not result in an increased germination count. This explains the fact that *D. glabra* strongly dislikes a waterlogged condition as described by Azene (1993).

Table 17: Treatment comparison using Tukey's pair wise comparison for the germination trials with different watering frequencies

Treatment	Mean Germination (%)
Watering everyday	66.67[ab]
Watering every other day	67.73 [a]
Watering every week	57.73 [b]

Figures connected by different superscript letters along a column are significantly different at 5% level of significance.

This is also another explanation for the conspicuous feature that *D. glabra* trees are rare at boarders of rivers while there are many in the dry salty plains adjacent to the river in Kala and Hirum rangelands (the study areas). An increase in water stress due to a watering frequency of only once a week significantly decreased the percentage of seeds germinated. This indicates that the threshold water potential or the minimum amount of moisture needed to initiate radicle emergence in the seeds (Hartmann *et al*., 2004) of *D. glabra* seeds is the amount of moisture that the seeds can obtain from a normal watering frequency of more than once a week. The inhibitive effect of reduced watering frequency (increased moisture stress) on germination, can also explain the fact that in the recent decades, new seedlings of *D. glabra* are a rare phenomenon. Local respondents repeatedly indicated that continuous and regular rain has been very uncommon in the study areas for the last two or three decades. Rains have been very erratic, short, untimely and unpredictable. So with this type of nature of rainfall and with extensive use of cooked *D. glabra* seeds as food, it is not surprising to see only old trees without seedlings. Therefore, it is clear that with the existing climatic crisis (unusual and short rains) and extensive use of the tree fruits as

food natural propagation of *D. glabra* is impossible and may eventually disappear in the long run. Therefore, ways of artificial propagation like nursery production of seedlings should be taken as options.

Mean germination count increased with increasing time after germination; this is because some seeds germinated late and thus were added to the average each time they germinated. However, a more important point is the week with the highest new germinations, as shown on the above table and figures; most of the seeds (about 70 %) germinated during the second week. Similar results were observed in our last germination experiments, therefore it can be concluded that seeds of the *D. glabra* tree germinate at about two weeks after germination. As indicated in figure 15, a higher moisture availability (watering each day) had no negative effect in the first two weeks after sowing. However, germination was retarded in the third and fourth weeks as compared to the other watering frequencies. This therefore, indicates that the water logging problem affects mainly the germination of seeds which are delayed, or which have already absorbed moisture before the actual emergence of radicle (germination). In this regard, Hartmann *et a*l. (2004) indicated that water logging or an excess amount of moisture can sometimes interfere with the physiological processes of germination and may result in the abortion of the germination process once initiated by the original moisture.

The reason that the daily watering frequency treatment resulted in a lower germination percentage than that of the every other day watering frequency is not only because germination was delayed, but also because some seeds that had started the germination process died before being counted or before emergence of the radicle. This is another explanation for the fact that *D. glabra* naturally avoids swampy soils.

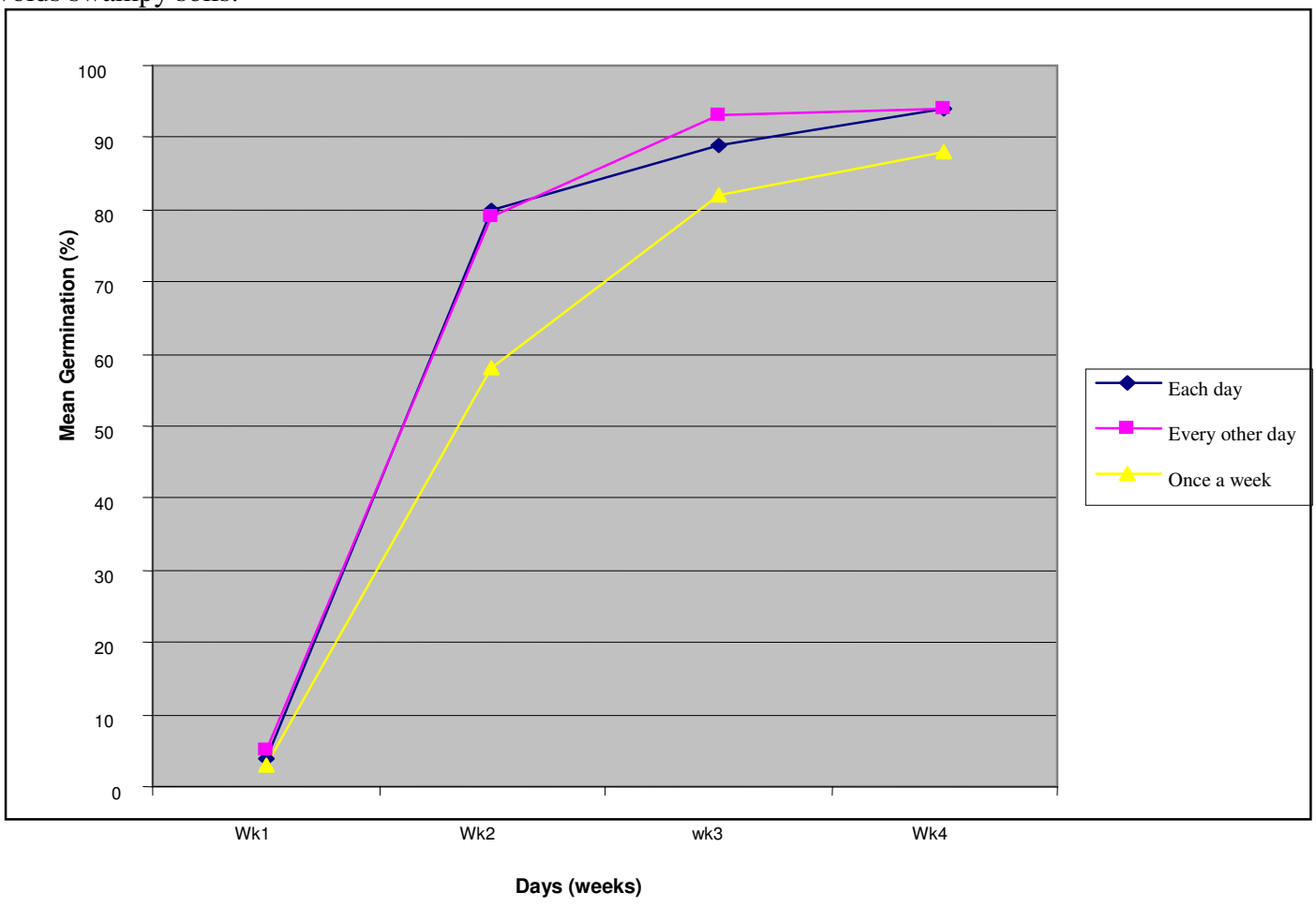

Figure 17: Mean germination percentage of D. glabra seeds under different watering frequency during the four weeks of germination time

4.4 PROPAGATION TRIAL FROM STEM CUTTING

This experiment had two treatments of stem cutting lengths of 15cm (T1) and 20cm (T20) in four replications. After planting, the stem cuttings were watered regularly. Successive strict observations, checking for callusing and bud initiation, were also undertaken on a daily basis. But finally, out of the two experimental groups (72 stem cuttings) none of them flourished a new shoot (callused). Instead, they completely dried up. Close observation for about three months gave no indication of the possibility of propagation from cuttings. The reasons for the inability of propagation from cuttings may vary. Bryant (1995) indicated that, even if some cuttings can be propagated at any time, there are other plants that require strict timing in taking cuttings for propagation. *D. glabra* can be one of the latter types of plants. Therefore, further investigation is required to see if time of cutting preparation is a factor for affecting the successfulness of propagation from cuttings. An important point here is that, whatever the reason for the failure to propagate from cuttings is, propagating *D. glabra* from cuttings would not be recommended for establishment or rehabilitation purposes, except for specific scientific or educational purposes. This is because for trees that produce more seeds which germinate easily or have no serious germination problem, direct sowing is recommended. Cutting is only a useful propagation method for plants that produce few seeds or no seeds at all, and for those which are difficult to grow from seeds (Bryant, 1995). *D. glabra* is a tree that produces enough amounts of seeds with reasonably high probability of germination. This is therefore the main reason why propagation from seed is the only recommended means of propagation for *D. glabra* given by Azene (1993).

4.5 NUTRITIVE VALUE AND CHEMICAL COMPOSITION OF THE EDIBLE PARTS OF *D. GLABRA*

4.5.1 Chemical composition of *D. glabra* leaf, twig and fruit

Mineral composition

Even though comparison of plant chemical composition from different areas with different sampling technique and growth stage is difficult, it can be possible to put a general range of estimation on the composition of *D. glabra*. The total mineral content of this plant is relatively higher than most of the browse plants of West Africa and even East Africa according to the 540 species in West Africa and East Africa of LeHouerou (1980) result analysis. It contributes 17.37-21.17 % of the dry matter. The highest value is obtained from the leaf while the lowest from the leaf and twig mixture.

The Ca content of the leaf and twig composite is extremely high (2.57-4.45% of DM) with an average value for all the sites of 3.48%, DM%. However, the P content is much lower than what has been found by LeHouerou in East and West Africa. It is within the range of 0.053-.13%, DM. This value is in fact better than most of the tropical dry season grasses. The Ca/P ratio is therefore too high, 36.8067, and is greatly beyond the limit for animal requirement, max 2.1 Ca/P ratios.

The K content is 1.66% which is almost similar to what has been found by LeHouerou (1980). But the Mg (1.16%) content is by far greater than the value presented by this author. The average Na percentage is 0.124%.

Crude protein

Plant samples (leaf and twig) collected from the different sites, regardless of age and composite proportion, show almost similar value for CP, in the range of 11-15.8% DM. This shows that animals with selective browsing ability on new shoots and leaves can benefit more than the value presented here. The fruit contains more protein than the leaves and twigs. As indicated in Table 18, Gid`a has the highest protein (23.25%) of all fruit parts.

Table 18: Chemical composition of *D. glabra* leaf, twig and fruit parts

Parts of the plant	Average values						
	CP%	**Ca**	**P**	**Mg**	**K**	**Na**	**Total Ash**
Leaf and twig (from 15 sample av.)	13.88	3.48	0.095	1.16	1.66	0.12	17.366
Leaf only (Three sample av.)	n	n	n	n	n	n	21.172
Fruit peel (Three sample av.)	13.1	n	0.04	n	n	n	9.29
Whole fruit (Three sample av.)	15.81	n	0.11	n	n	n	8.84
Gid`a	23.25		0.14				6.59
Garsa (consumed after boiling) (Three sample av.)	17.18	n	0.16	n	n	n	5.77
Red flesh (consumed by the people) (Three sample av.)	15.84	n	0.06	n	n	n	14.45

n = data not available for the report.

D. glabra edible foliage is also an important source of water in the dry season as it consists of a high amount of moisture in the leaves (more than 45 percent).

4.5.2 Soil-plant nutrient correlation

The correlation of plant foliage Ca level and soil CaCO3 indicated in table 24 shows that it has a positive value of 0.681 (Table 19). This result implies that the plant exploits the soil's Ca content to incorporate into leaf and twig components. The correlation of P with soil CaCO3 is however greater than the Ca correlation value implying that a higher P intake and incorporation into the plant part is directly dependent on soil Ca level.

Table 19: Correlation of plant and soil chemical composition

Function	**Value**
Correlation b/n foliage Ca level and soil CaCO3	0.681
Correlation b/n foliage P level and soil CaCO3	0.707
Correlation b/n foliage Nitrogen and OM	
Correlation b/n foliage Mg and soil CaCO3	0.586

The soil data for other mineral contents was not available and comparison and correlation was impossible.

4.5.3 Nutritive value of edible parts of *D. glabra* fruit

Appreciating its importance for the Afar pastoralist community, and to extract more information on this very important wild food, nutritional analysis was made on the two parts of the fruit (Gersa, the green most internal, and the red peel of Gersa). The results are presented in Table 20.

Table 20: The nutritive value of edible parts of *D. glabra* fruit

S.N	Parameter measured	Seed form	
		Gersa Green	**Red peel**
1	Moisture (%)	28.10	7.50
2	Fat (%)	0.46	1.75
3	Protein (%) (N*6.25)	16.00	7.50
4	Ash (%)	6.79	14.52
5	Crude fiber (%	2.41	2.82
6	Carbohydrate (%) including crud fiber	48.65	68.73
7	Energy (Kcal/100g)	253.10	309.39
8	Iron (Fe), mg/100g	2.82	4.61
9	Calcium (Ca), mg/100g	350.7	2,897.27
10	Zinc (Zn), mg/100g	2.91	120
11	Copper (Cu), mg/100g	0.3	0.45

Analysis of nutritional values of some wild fruits in Makuiney District, Kenya by Thingo et al. (http://www.actahort.org/members/showpd), showed the following nutritional result: Vitamin C values in the pulp and skin fraction ranged from 90 to over 300 mg/100 g of fresh matter, sugar content varied between 7 and 11% of sucrose. Total acidity was around 2%, and the embryos, consumed like nuts, contained over 50% fat. Most minerals were present in only small amounts. A similar study on 27 wild edible plants in the Sikkim Himalia by Sundriyal et al, (2004) (http://www.bioone.org/bioone/) gave the following results: Crude fiber content ranged between 2.15–39.90%, total sugar from 2.10–25.09%. All these results were ranked as promising by the authors and it is said that the nutritive values of some of the wild edible species determined in these studies are comparable with various commercial fruits. The results for *D. glabra* show that it is comparable with the results of these studies and better in some cases, especially carbohydrate contents which are 48.65 % and 68.73% for the green Gersa and the red peel respectively. This therefore, indicates that *D. glabra* fruits have a reasonably good nutritional value.

However, the way the Afar pastoralists utilize the fruit, which is by cooking is inevitably expected to reduce its nutritive value. According to our respondents, it is said that the fruit is cooked for about 24 hours before consumption. The respondents also indicated that the reason they cook the fruit is to avoid some unpleasant side effects such as bad taste, stomachache, constipation and diarrhea. Therefore, it is important to look for means of improving the taste and palatability of the fruit without reducing its nutritive value. One way of doing this can be by using rainwater for reducing cooking time and thus the level of loss of nutritive value. In our cooking experiments using rainwater was observed to reduce the cooking time by about 18 hours (from 24 hours to 6 hours).

4.6 COOKING TRIAL

From the socio-economic survey it was observed that *D. glabra* seeds (Garsa) require a long cooking period to make them ready for human consumption. To know the reasons for the long cooking period requirement of *D. glabra* seeds, 24 hours as suggested by Azene (1993), trials were conducted using water samples from different localities; Kuwiha tap water, Aba`ala tap water (underground), Aba`ala river water and rainwater were used. This problem was hypothesized to be due to the hardness of the local cooking water. Under this experiment the native experienced Afar ladies were selected for the cooking and as witnesses to detect how cooked the seeds were at time intervals.

The time record analysis for complete cooking (appendix 2.3) showed that there does not exist a significant difference among the treatments at ($p>0.05$). However, rainwater brought improvement

in reducing the time and energy spent to completely cook *D. glabra* seeds. As a result, the minimum time record is obtained with rainwater treatment and next Kuwiha tap water as shown in Table 21. Although it is difficult to generalize, rainwater and the highland water may improve the cooking period. Neither of these water types brought any unique taste and flavor to the cooked seeds during consumption.

Table 21: Mean comparison of time taken for safe cooking of *D. glabra* seeds

Water types as treatment	**Mean time taken for safe consumption (In minutes)**
Aba`ala Tap water	296.67[a]
Aba`ala river water	290.00[a]
Kuwiha tap water	233.33[a]
Rain water	223.33[a]

Values not connected by the same letter are significant

The local people reported that the cooking water of *D. glabra* seeds has a bad smell and Azene (1993) has also supported this. However, this could not be observed in this research, which might be due to the freshness of the seeds and the short storage period before cooking (only a month). Therefore, this phenomenon needs further investigation.

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The study finds that *D. glabra* is an important plant for the Afar people and is among the few ranked species in the area as it has a social, economic and cultural value to the pastoralists as being:

- a human food source;
- an important browse tree for domestic animals particularly for camels;
- a well known drought indicator plant;
- a traditional medicine for both human and animal diseases;
- an important shade tree;
- a highly drought resistant plant and hence persistent in the rangeland even during drought is a respected plant in their culture.

The role of this plant in providing human food is more practical during drought periods. But it needs a long cooking period and high consumption of fuel wood. In addition, it is also an important wild fruit plant for the herders in the field during normal times. However, the consumption of *D. glabra* and other wild foods is a cultural taboo in the study area and is assumed to indicate lower strata in the community.

Eventhough *D. glabra* favors a hot, moist and windy environment and is an essential drought resistant plant for the pastoralists in the rangeland, it is nowadays facing a drastic decrease in population from the plain of the rangeland and remaining only as riverside vegetation. The variable and untimely rainfall distribution of the study area is, according to the pastoralists, the major cause of failure to regenerate itself. Despite this and other reasons leading to this phenomenon (tree cutting, shift in browsing of domestic and wild animals on *D. glabra* due to over grazing of the rangeland, seedling damage by insects and worms, unknown germination problem), *D. glabra* is known for its seed propagation method.

From the different germination trials, the failure in natural regeneration of *D. glabra* is not associated with the germination ability of the seed. In spite of the germination delay relative to the short and erratic rainfall distribution in the area, all the three types of seeds show a germination percentage of more than 30% for Gallolo, 40% for Gid`a and 50% for Garsa at 28 days count after sowing without any treatment. But after 45 days count, more than 85 % of the seeds germinated in all cases. Therefore, the biggest reason for these failures may be the unavailability of adequate moisture in the area which undeniably impacts the regeneration of this plant. Similarly, results of the germination trials for different watering frequency indicated that most seeds failed to germinate well under rich moisture condition and extreme moisture deprivation. This therefore indicates that the erratic and untimely nature of the rain can be causing the problems of seed germination. In other words, it means that the type of rainfall in those areas is either too much rain at once (waterlogged condition) or no rain or extreme deprivation. Some pastoralists also remarked that the time when seeds fall and are ready for germination is different with the time when moisture is reasonably available to initiate germination.

Treatment of the seeds (Gid`a and Garsa) before sowing was indeed capable of reducing germination delay at least by a week's period on average. Soaking in cold water for 24 hours brought 80% germination achievement in four weeks time. This was particularly more prominent in the Garsa seeds. In most cases, Garsa seeds are faster at germination than the other forms without any treatment. Comparison of the germination ability of the three seed forms also indicated that the Gallolo type of seed germinated late or its germination was delayed. The reason

why the Gallolo seeds germinated at the end was only because watering was continuous. However, under natural conditions where there is only a short period of moisture availability, Gallolo or the seed form with its kernel can be the reason for germination failure.

From the cooking trial analysis, a general conclusion could not be reached that the problem can be solved using one of the different water types to reduce the long cooking period and high energy consumption. However, rainwater and Kuwiha water (high land water with elevation of greater than 2000m a.s.l) samples brought improvement in reducing this time by an average of one-hour. Therefore, the major problem of a long cooking period requirement is due to the nature of the seed.

Analysis of the chemical composition and the nutritive value of the edible parts of *D. glabra* indicates that the foliage or leaves of the plant is a very good source of water for browsing animals during the dry season. Besides, the leaves have a higher amount of mineral content (17.37- 21.17 % of the total dry matter) especially calcium as compared to most common brows. Analysis of the different parts of the edible fruit for nutritional content revealed that *D. glabra* has a nutritive value very comparable to the known wild fruits.

The absence of young 'Gersa' seedlings in an area is related to low moisture availability at the time of germination and this can be justified by low organic matter, which is key for improving water-holding capacity.

5.2 RECOMMENDATIONS

According to the information revealed in the research, the following recommendations are important for future protection and development of the plant and its values:

- More attention has to be given in keeping this plant from being endangered in the rangeland. Since the main observed problem is failure of recruitment, the first objective of any endeavor in the protection of this plant should be making seedlings available. As observed in the different germination trials in the study, producing and establishing seedlings in a nursery site is not a very difficult task. This therefore indicates that the number of seedlings in the rangelands can be increased by producing seedlings in a nursery and planting them at the beginning of the rainy season. This off course has to be accompanied by seasonal animal exclusion from the rangelands.
- Establishment of *D. glabra* seedlings by soaking in cold water for 24 hours should be used.
- Large amounts of fuel wood consumption during the cooking process of *D. glabra* must be given due emphasis to avoid deforestation problems. Therefore, other better methods of preparation of for example porridge need to be introduced.

The absence of young 'Gersa' seedlings in an area is related to low moisture availability at the time of germination and this can be justified by low organic matter, which is key for improving water-holding capacity. To alleviate this problem some parts of the rangeland can be seasonally protected from animal access so that organic matter can be accumulated since the short lived annual plants will not be grazed, rather they will be incorporated into the soil.

5.2.1 Further research

D. glabra is one of the most important plants in Afar and needs greater attention. In this, regard more in-depth scientific studies are required on the effect of browsing and habitat factors on natural recruitment, effect of storage period on seed viability, and survival of transplanted and naturally established seedlings.

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2 A. Aune, J.B. and Doumbia, M.D. 1998: "Integrated Plant Nutrient Management (IPNM), Case studies of two projects in Mali: CARE Macina programme and PIDEB", Drylands Coordination Group and Noragric, Agricultural University of Norway.

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